

SPACE STATION  
SIMULATION COMPUTER SYSTEM (SCS) STUDY  
for  
NASA/MSFC

**BASELINE ARCHITECTURE  
REPORT - VOLUME 1**

TRW-SCS-90-XT2

21 December, 1990

**TRW**

**ESSEX**  
CORPORATION

**GRUMMAN**

(NASA-CR-184368) SPACE STATION  
SIMULATION COMPUTER SYSTEM (SCS)  
STUDY FOR NASA/MSFC. VOLUME 1:  
BASELINE ARCHITECTURE REPORT Study  
Report, Jan. - Dec. 1990 (TRW)  
113 p

N92-33487

Unclass

G3/60 0321270

**V System Development  
sion**  
ems Integration Group

213 Wynn Drive  
Huntsville, AL 35805  
205.837.2400

SN51946.000  
G002.VOB.90-3426  
21 December 1990

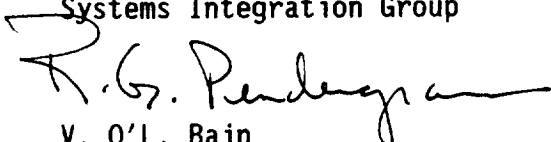
National Aeronautics and Space Administration  
George C. Marshall Space Flight Center  
Marshall Space Flight Center, AL 35812

Attn: Mr. M. Watson/E035

Subject: Contract No. NAS8-37745  
Baseline Architecture Report  
Simulation Computer System for Space  
Station Program

In accordance with the requirements of the subject contract,  
the technical report titled Baseline Architecture Report is  
herewith submitted and distributed as shown.

TRW Inc.  
Systems Integration Group

*for*  
  
V. O'L. Bain  
Contracts Administrator  
Huntsville Operations  
System Development Division

**Distribution:**

AP52 (1)  
CN22D (5)  
AT01 (1)  
CC01 (1)  
E035 (20)  
KA02 (1)  
NASA Scientific and Technical Information Fac. (2)  
EM12A-16 (1)

SPACE STATION SIMULATION COMPUTER SYSTEM (SCS)  
STUDY

**BASELINE ARCHITECTURE  
REPORT**

SCS

SCS



SCS

SCS

CDRL: TRW-SCS-90-XT2

21 Decmber, 1990

Approved By:

A handwritten signature in cursive script, appearing to read "J. H. Jensen".

-----  
J. H. Jensen, Manager  
SCS

Released By:

A handwritten signature in cursive script, appearing to read "P. G. Dombrowski".

-----  
P. G. Dombrowski, Manager  
Huntsville Systems Laboratory

SCS

SCS

Under:

Contract No. NAS8-37745/P00002

Prepared for:

NASA  
MSFC EO-35  
Huntsville, Alabama 35812

Prepared by:

TRW System Development Division  
213 Wynn Drive  
Huntsville, Alabama 35805

TABLE OF CONTENTS	PAGE
INTRODUCTION	1
1.0 TRAINING REQUIREMENTS	2
1.1 TRAINING OBJECTIVES	2
1.2 TRAINING LOADING ANALYSIS	4
1.2.1 Final Training Loading Analysis	4
1.2.3.1 Crew Training	5
1.2.3.2 POIC Training	5
1.2.3.3 Principal Investigator Support	8
1.2.3.4 PTC Personnel	8
1.2.3.5 Training Resource Estimate	8
1.2.3.5.1 45-Day Crew Increments	8
1.2.3.5.2 90-Day Crew Increments	9
1.2.2 Training Loading Summary	11
2.0 RELATED SSFP DESIGN INFORMATION	13
2.1 SSTF DESIGN	13
2.2 DMS KITS	15
2.3 SIB	16
2.4 OMA	17
2.5 SSE/ITVE	17
2.6 SIMULATION STANDARDS	17
2.6.1 Simulation Control Method	17
2.6.2 Simulation Modes	18
2.7 HARDWARE AND SOFTWARE STANDARDS	18
3.0 PTC/SCS ARCHITECTURE TRADEOFFS	19
3.1 COMMON ARCHITECTURAL ELEMENTS	19
3.1.1 Software Architecture	19
3.1.2 Hardware Architecture	28
3.1.2.1 System Design	29
3.1.2.1.1 General Description	29
3.1.2.1.2 Network Architecture	31
3.1.2.2 Trainer Design	31
3.1.2.2.1 Host Architecture	33
3.1.2.2.2 Model Representations	33
3.1.2.2.2.1 Payload Representation	33
3.1.2.2.2.2 Payload Stimulation	34
3.1.2.2.2.3 Payload Panels	34
3.1.2.2.2.4 Core Systems Representation	35
3.1.2.2.2.5 Crew Interface Representation	35
3.1.2.2.2.5.1 C & D Panels	35
3.1.2.2.2.5.2 Crew Console - Multipurpose Application Consoles (MPACs)	36
3.1.2.2.2.6 Audio/Video Systems Representation	36
3.1.2.2.3 DMS Components	36
3.1.2.2.4 Trainer Connectivity	37
3.1.2.2.4.1 Consolidated Trainer	37

3.1.2.2.4.2 Other Trainers	37
3.1.2.3 Support Facilities	37
3.1.2.3.1 Development Facility	37
3.1.2.3.2 External Interfaces	38
3.1.2.3.3 POIC Trainers	38
3.1.2.3.4 IT&V Facility	38
3.1.2.3.5 CBT Stations and Facility	39
3.1.2.4 Simulation Control and Monitoring	39
3.1.2.4.1 Session Management Function (SMF)	39
3.1.2.4.2 Instructor Stations	39
3.2 Cost Drivers	40
3.2.1 Type of C&D Panel Crew Interface:	42
3.2.2 Type of MPAC Crew Interface :	44
3.2.3 Fidelity of Payload Models:	46
3.2.4 Fidelity of Core Systems Models:	49
3.2.5 Fidelity of Environment Models:	51
3.2.6 Use of DMS Kits:	53
3.2.7 SIB's Interface to Host Computer:	57
3.2.8 Use of MDMs:	59
3.2.9 Use of OMGA	61
3.2.10 Concurrent Independent Training Sessions	62
3.2.11 Per Cent of Flight Equivalent Payload Simulations:	64
3.2.12 Trainees and Payloads per Quarter:	66
3.2.13 Payload Changeout per Increment:	67
3.2.14 Representation of DIF:	69
3.2.15 Software Payload Models Developed on PTC/SCS:	70
3.2.16 PTC/SCS Remote Developer Capability:	72
3.2.17 Consolidated Increment Training:	74
3.2.18 POIC Interface:	76
3.2.19 Training Sessions with UOF/ROC/DOCs:	78
3.2.20 Use of MODB/RODB:	79
3.2.21 Use of Ada:	80
3.2.22 Use of SSE/ITVE Tools:	81
3.2.23 Payload Simulator Transportability to SSTF:	83
3.2.24 Simulator Transportability between Module and Part-Task Trainers:	86
3.2.25 Attached Payload Representation:	88
3.2.26 Payload Video Representation:	89
3.2.27 Flight equivalent Payload GSE:	91
3.2.28 Payload Stimulation:	92
3.2.29 Instructors per Trainer :	94
3.2.30 U.S. Payloads in International Partners' Modules:	96
3.2.31 Trainer Host Reconfigurability:	98
3.2.32 Malfunction Insertion:	100
3.2.33 Simulator Modes:	102
3.2.34 Session Data Handling:	105

VOLUME 2	PAGE
4.0 CONCLUSIONS AND RECOMMENDATIONS	107
4.1 COST EFFECTIVE SOLUTION	110
4.2 CBR BASELINE	113
4.3 LOW COST BASELINE	115
4.4 LOW FIDELITY, LOW COST BASELINE	119
4.5 OTHER DESIGNS	123
GLOSSARY	133
APPENDIX A - SYSTEM SIZING ANALYSIS	136
APPENDIX B - SOFTWARE SIMULATION FIDELITY LEVELS	157
APPENDIX C - TRAINING LOADING ANALYSIS	158

## INTRODUCTION

The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Space Station Freedom (SSF) Payload Training Complex (PTC) at MSFC. The PTC will train the SSF station operators, payload scientists, station scientists, and ground controllers to operate the wide variety of experiments that will be on-board the Freedom Space Station.

This SCS Baseline Architecture Report summarizes the further analysis performed on the SCS Study as part of Extension Task 2 - "Develop an SCS Baseline Architecture" - of the SCS Study contract extension. These analyses were performed to develop the most cost effective solution to the PTC/SCS development requirements, and to identify and quantify the SCS cost drivers.

**To accomplish this task the TRW team performed the following steps:**

- Compiled from available sources current payload training requirements for SSF payload deployments. This included reviewing the requirements as stated in the SCS Concept Document, review of the Training FCD, and numerous meetings with the MSFC Training Branch personnel.
- Compiled and reviewed current technical design information from WP02 on DMS Kits, SSE simulation, simulation control, simulation standards, hardware and software standards, and SIB. We also reviewed existing SSTF interface requirements and design, and the PTC/SSTF Interface Requirements Document (IRD).
- Reviewed the above information with MSFC Training Branch to identify the minimal set of training and simulation requirements that must be met by a cost effective baseline AC PTC/SCS configuration.
- Identified the PTC/SCS cost drivers, identified realistic definitive options, and developed a table that allowed quantifiable choices leading to the most cost effective baseline solution.
- Defined AC baseline software architecture details
- Defined AC baseline hardware architecture details.

## **1.0 TRAINING REQUIREMENTS**

### **1.1 TRAINING OBJECTIVES**

The objectives of training at the PTC/SCS are shown in Figure 1. The Onboard Training was removed during the CBR scrub, but is shown in Figure 1 for traceability purposes. There is currently a CR that has been submitted to reinstate some form of onboard training, but for now onboard training is out of the program, and will not be further considered in the SCS Study. Previously (see SCS "Study Analysis Report", Issue T-20), it was concluded that onboard payload training requirements were best met via portable audio/video tapes and disks, or self contained PC based simulations.

The Consolidated Payload Simulation training purpose of training crew in the PTC with personnel at the ROCs, DOCs, and UOFs is a new requirement on the PTC/SCS, and thus is not currently incorporated in the PTC or SCS requirements. If the POIC is involved in all of the Consolidated Payload Simulation training sessions, this requirements should have little affect on the PTC/SCS requirements. If however, the PTC/SCS is to conduct this type of training without the POIC, the PTC/SCS would have to simulate the POIC, and even potentially the SSCC. For example, if the PI at a ROC, DOC, or UOF exceeded his resource allocation, the POIC would intercede. If the PI then requested additional resources, the Onboard Short Term Plan (OSTP) would have to be redone. This is an SSCC function.



Training Type	Objective
Computer Based Training	Will train individual students utilizing scenarios without instructor intervention -- basic use will be to provide preliminary or introductory instruction via screen text and graphics combined with questions to which the student would respond.
Part-Task Training	Primarily for developing single crew member operating skills associated with individual payload flight operations. Will also be utilized for the development of ground support personnel operating skills associated with individual payload operations.
Combined Training	Primarily for training a team of 2 or more crew members to operate multiple payloads combined into specific labs. Supports the combination of crew members and ground support personnel for training on payload operations specific to a lab.
Consolidated Training	Primarily for training 4 or more crew members located in Freedoms modules or the combination of crew members and ground support personnel for training on integrated payload operations throughout the entire manned base.
SSTF Integrated Training	Allows a student team to train on an entire mission increment at JSC with payload simulators running in a full-scale mode with the SSTF.
Consolidated Payload Simulation	Purpose is training crew at the PTC with teams of students at other operations centers, (e.g. the POIC and/or user operations centers – ROCs, DOCs, and UOFs) on specific flight increment objectives including reworking the short term plan, payload operations and updates, interactions with telescience operators, shift handovers, and payload malfunctions.
POIC Training	POIC Cadre members and certain representatives of remote operations centers can train on POIC systems, protocols and procedures using a representative subset of POIC components.

**Figure 1. PTC/SCS Training Objectives**

## 1.2 TRAINING LOADING ANALYSIS

The estimation of the training loading on the SCS was an iterative process that was complicated by the lack of detailed definition of the Space Station Program. There is little experience/data to draw from that is considered to be directly applicable to the Space Station training hour estimation. An initial estimate was evaluated in the original study. In this study extension, a detailed analysis was performed using Spacelab data and current definition of the Space Station Program. A final analysis was also performed with new training hours estimates and the latest OSSA payload traffic schedule, inputs from the Spacelab J mission training manager, and the current best estimates from the WP01 prime contractor. The detailed analysis is presented in Appendix C as a reference. The following section presents the final analysis and conclusion of the study analysis that was performed in each step of this training estimation process.

### 1.2.1 Final Training Loading Analysis

The review of the Spacelab analysis (See Appendix C) by training personnel indicated that the estimated number of total training hours was too large. A number of questions were raised concerning the applicability of Spacelab and particularly the Astro mission. Therefore, NASA training personnel and WP01 contractor personnel were tasked to develop an independent estimate of crew training hours. Using this latest data, the increment flow was analyzed to determine concurrent training operations.

One other item that was questioned was the changeout rate which was assumed to be 15% of the payloads each 90-day increment. Using the OSSA Space Station Program Payload Traffic Model dated 10 May 1990, the changeout rate was re-evaluated. The calculation is based on the scheduled racks at AC and the scheduled changes over the next 4 years. The rate is calculated as follows:

Number of racks at AC = 13

Number of racks changed out in 4 years = 2.5

Changeout rate for 4 years =  $2.5/13 = \sim 19\%$

Changeout rate per year =  $19\%/4 = \sim 5\%$

Changeout rate per increment =  $5\%/4 = 1.25\%$

Due to the uncertainties of current schedules, we will assume a 5% changeout rate to ensure a reasonable upper bound. Also, the changeout rate only affects the PI and PTC personnel support and not the number of crew to be trained. Therefore, it has a minimal impact on the overall requirements.

The following sections provide the updated analysis based on the new training estimates received from WP01 personnel and the new changeout rate.

### 1.2.3.1 Crew Training

Analysis shows that the driving factor for facility needs is the number of concurrent training sessions required to support the increment training schedule. Therefore the new hour estimates were mapped onto the increment flow to determine the concurrency. The hours developed per crew member (excluding the station operator) are:

PTT hours	300
Modules hours	535

The time frame used in our final analysis for training in the PTC is between L-12 and L-6 which affords 6 months. Since the latest training estimates only consider crew training expected on PTTs and in the module trainer, the remaining hours in the 6-month window were split between CBT/Classroom training and consolidated training. The resulting schedules are pictured in Figure 1.2-1 for 45-day increments and Figure 1.2-2 for 90-day increments.

**The new estimates from this analysis are as follows:**

CBT/Classroom Training	105 hours
Part Task Training	300 hours
Module Training	535 hours
<u>Consolidated Training</u>	<u>100 hours</u>
Total hours in 6-month window	<b>1040 hours</b>

### 1.2.3.2 POIC Training

The only changes to the POIC training are due to the assumed 5% changeout rate which affects the incremental training. The training hours are:

**New Personnel**

No changes from prior analysis - 4075 CBT training hours per year

**PMC**

Launch Number: 12, 13, 14, 15, 16, 17, 18, 19, 20, 21

**Legend:**

- PTC Class/CBT Training
- PTC Individual P/L Training
- PTC Module P/L Training
- PTC Consolidated P/L Training
- PTC POIC Training
- SSTF Training
- Consolidated
- Payload Simulation

**Crew Members and Training Periods:**

- Crew 13-1: Launch 12-13
- Crew 13-2: Launch 12-13
- Crew 14-1: Launch 13-14
- Crew 14-2: Launch 13-14
- Crew 15-1: Launch 14-15
- Crew 15-2: Launch 14-15
- Crew 16-1: Launch 15-16
- Crew 16-2: Launch 15-16
- Crew 17-1: Launch 16-17
- Crew 17-2: Launch 16-17
- Crew 18-1: Launch 17-18
- Crew 18-2: Launch 17-18
- Crew 19-1: Launch 18-19
- Crew 19-2: Launch 18-19
- Crew 20-1: Launch 19-20
- Crew 20-2: Launch 19-20
- Crew 21-1: Launch 20-21
- Crew 21-2: Launch 20-21

**Required Module P/L Training**

**Required Consolidated Increment Training**

**SSTF Configuration**

Increments are assumed to be launched on 3 month centers. First payload launch after PMC is the 13th.

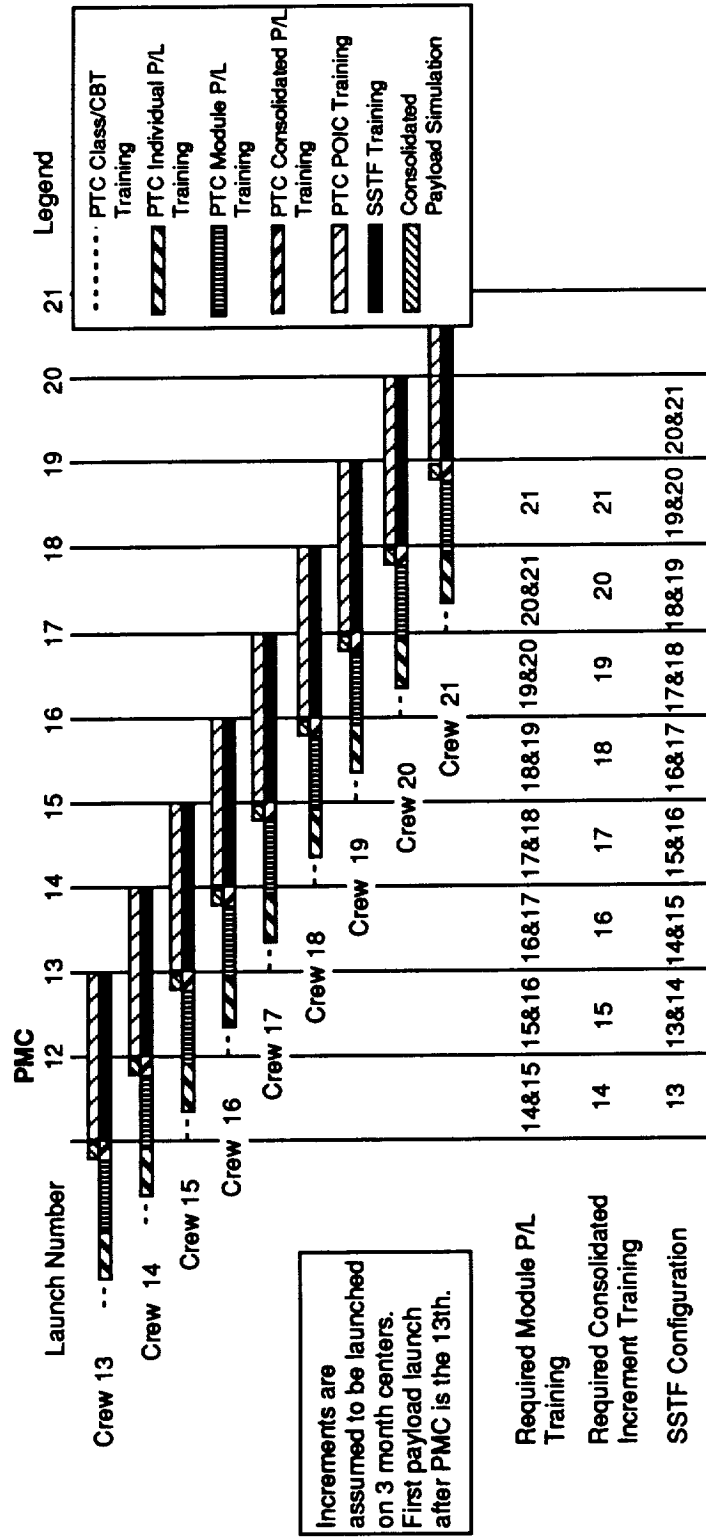


Figure 1.2-2. Final Training Increment Flow Analysis – 90-Day Payload Increments/90-Day Crew Increments

### **Incremental Training**

Assume 4 hours CBT per experiment

Assume 2 experiments per increment (5% changeout) for U.S. Lab

Assume 1 experiment per increment (5% changeout) for U.S. sponsored in IP

Assume 5 crews of 25 (125 personnel)

125 (personnel) X 3 (experiments) X 4 (hours) = 1500 hours per 90-day increment

4 increments/year X 1500 = 6000 hours/year

#### **1.2.3.3 Principal Investigator Support**

The 5% changeout rate modifies the calculations as follows:

CBT Training (2 U.S. Lab exp. X 4 hours training) = 8 hours/increment

4 increments/year X 8 = 32 hours/year

U.S. Lab PTT use per increment (2 exp. X 80 hours/exp.) = 160 hours/increment

IP PTT use per increment (1 exp. X 80 hours) = 80 hours

#### **1.2.3.4 PTC Personnel**

The PTC personnel support estimation is modified due to the new changeout rate. The CBT hours for new personnel remains at 280 per year. The calculation for incremental CBT course development must now assume only 3 experiments per increment for U.S. Lab and IP. Therefore, the additional CBT hours are:

3 exp. X 20 (hours for each exp.) = 60 hours per 90-day increment

#### **1.2.3.5 Training Resource Estimate**

The new estimation of concurrent sessions and the new hours estimates does impact the prior resource estimation. The following sections re-evaluate the 45-day and 90-day crew increments for facility resource needs.

##### **1.2.3.5.1 45-Day Crew Increments**

#### **CBT**

1 crew of 4 training simultaneously	4
New POIC personnel	2
Incremental POIC personnel training	3
<u>PI and PTC personnel support</u>	<u>1</u>
Number of concurrent CBT sessions	10

**PTT**

2 crews training simultaneously (2 per PTT)	4
<u>PI support</u>	<u>1</u>
PTTs in concurrent use	5

Based on the number of U.S. Lab experiments (43) and the number of U.S. sponsored experiments in the IP modules (17), the configuration of PTTs includes U.S. Lab (2 PTTs for U.S. Lab payloads) and IP (1 PTT for JEM and 1 PTT for Columbus). Some time on the PTTs must be available to support the PI activity for payloads in the different IP modules, but the demand for U.S. Lab PTTs indicates the need for an additional PTT for the PI support. Since the PTTs will be different for each module, this implies that a total of seven PTTs must be available to meet the possible training schedules and provide available time for PI support. The total number of configured PTT sessions that must be available at certain times in the training schedule are:

PTTs for U.S. payloads in the U.S. Lab	5
(4 for crew and 1 for PI support)	
PTTs for U.S. payloads in the JEM	1
<u>PTTs for U.S. payloads in the Columbus</u>	<u>1</u>
Concurrently available PTT sessions	7

**Module**

Analyzing the training schedule shows two crews at a time will need to be trained, so two U.S. Lab modules will be necessary to support training. It is expected that a single Attached Payload Trainer will suffice to support training in the two U.S. Lab trainers.

**Consolidated**

Only one crew at a time will need to be trained, so only a single Consolidated Trainer will be necessary to support training. The Consolidated Trainer must include a U.S. Lab module, a JEM module, an Attached Payload Trainer, and a Columbus Module. Since the 45-day increment flow shows simultaneous use of 2 module trainers and 1 consolidated trainer, a third U.S. Lab module will be necessary. It is expected that the Attached Payload Trainer can be the same one used to support U.S. Lab module training.

**1.2.3.5.2 90-Day Crew Increments**

If we evaluate the needs based on a 90-day crew increment, only those numbers involving the crew training must be modified. The following estimates are based on the 90-day flow shown in Figure 1.2-5.

**CBT**

1 crew of 4 training simultaneously	4
New POIC personnel	2
Incremental POIC personnel training	3
<u>PI and PTC personnel support</u>	<u>1</u>
Number of concurrent CBT sessions	10

**PTT**

1 crew training simultaneously (2 per PTT)	2
<u>PI support</u>	<u>1</u>
PTTs in concurrent use	3

Based on the number of U.S. Lab experiments (43) and the number of U.S. sponsored experiments in the IP modules (17), the configuration of PTTs includes U.S. Lab (2 PTTs for U.S. Lab payloads) and IP (1 PTT for JEM and 1 PTT for Columbus). Some time on the PTTs must be available to support the PI activity for payloads in the different IP modules, but the demand for U.S. Lab PTTs indicates the need for an additional PTT for the PI support. Since the PTTs will be different for each module, this implies that a total of 5 PTTs must be available to meet the possible training schedules and provide available time for PI support. The total number of configured PTT sessions that must be available at certain times in the training schedule are:

PTTs for U.S. payloads in the U.S. Lab	3
(2 for crew and 1 for PI support)	
PTTs for U.S. payloads in the JEM	1
<u>PTTs for U.S. payloads in the Columbus</u>	<u>1</u>
Concurrently available PTT sessions	5

**Module**

Analyzing the training schedule shows only one crew at a time will need to be trained, so only a single U.S. Lab module and a single Attached Payload Trainer will be necessary to support training. There will be available time in the module trainer to support needed time for individual payload training.

**Consolidated**

will be necessary to support training. The Consolidated Trainer must include a U.S. Lab module, a JEM module, an Attached Payload Trainer, and a Columbus module. Since the 90-day increment flow shows simultaneous use of a module trainer and a consolidated trainer, a second U.S. Lab module will be necessary. It is expected that the Attached Payload Trainer can be the same one used to support U.S. Lab module training.



### 1.2.2 Training Loading Summary

The biggest driver for the facility loading is the number of concurrent sessions that must be supported for the increment schedules. Therefore, the two possible crew increments of 45-day and 90-day make significant changes in the loading estimates. The final analysis performed using training hours estimates provided by NASA and WP01 training personnel and the latest payload traffic estimates are the best estimate that can be determined at this time. Therefore, the SCS components that are required to support the demand for concurrent operations at various points in the training schedule based on the latest PTC training estimates are listed below based on the two possible crew increments.

#### 45-Day Crew Increment

CBT Stations	10
Part Task Trainers:	
U.S. Lab	5
JEM	1
Columbus	1
Total	7
Module Trainers:	
U.S. Lab	2
Attached Payload	1
Total	3
Consolidated Trainer	1
Includes:	
1 U.S. Lab module (additional U.S. Lab module)	
1 JEM module	
1 Columbus module	
1 Attached Payload (same module as above)	

#### 90-Day Crew Increment

CBT Stations	10
Part Task Trainers:	
U.S. Lab	3
JEM	1
Columbus	1
Total	5

#### Module Trainers:

U.S. Lab	1
----------	---

<u>Attached Payload</u>	<u>1</u>
Total	2
Consolidated Trainer	1
Includes:	
1 U.S. Lab module (additional U.S. Lab module)	
1 JEM module	
1 Columbus module	
1 Attached Payload (same module as above)	

## 2.0 RELATED SSFP DESIGN INFORMATION

Since the PTC/SCS will use or interface to other SSFP elements, the requirements and design of these elements will have a strong influence on the PTC/SCS baseline architecture. A discussion of each of these key elements and the anticipated influences follows.

### 2.1 SSTF DESIGN

The same payload models that are used in the PTC are planned to be used in the SSTF for whole station training. Utilizing a second set of payload models at the SSTF would not be cost effective, nor good training practice as there would inevitably be differences in the models. Additionally, the models transported from the PTC to the SSTF must arrive at the SSTF in a "plug and play" state. If a conversion or modification of the payload models is required when they arrive at the SSTF, this must be accompanied by an integration, test, and acceptance cycle. This type of activity would take some number of weeks, and neither the PTC nor the the SSTF training schedule contain weeks of slack. Since the actual payload is scheduled to begin flight integration at L-12 to L-9, the payloads model will be evolving as changes are made until L-6 and perhaps even later. Thus, the models will at best be mature and ready to ship at L-6. Consequently, there exists a derived requirement that payload models from the PTC be installed and ready to use at the SSTF in a few days at the most.

CAE Link was awarded the SSTF development contract in October '89. They are currently performing requirements analysis, doing preliminary design, and defining Level B specifications. Since they have no budget or reason to develop a second set of payload models for each increment over the 30 year lifetime of the SSF, they are working to build a design that will permit the easiest transport of the PTC payload models to the SSTF. Thus the current SSTF design supports the transportability requirement, with one notable exception. The exception is that there is no provision in the current SSTF design for using flight equivalent Multiplexers/ Demultiplexers (MDMs), which means no support for flight equivalent payload hardware that interfaces to MDMs or payload flight software that executes in MDMs.

As shown in Figure 2, there is a separate host computer in the SSTF called the Payload Session Computer to run the payload models. This computer interfaces to the C&D panels in the mockups (Hab, Lab and Nodes) via the Real-Time (RT) LAN, the DMS Kits via a SIB, and the Software Production Environment, IT&V, and Operations Support computer via the General Purpose (GP) LAN. The Multipurpose Applications Consoles (MPACs) are connected to the DMS Kit FDDI, just as the flight MPACs are connected to the DMS FDDI. The Payload Session Computer is connected to the Core Session Computer via the Session Real-Time (RT) LAN.

No actual hardware has yet been selected to support the SSTF design. The most optimal selection to guarantee turn-key transportation of payload models to the SSTF would be to select the same host for the SSTF Payload Session Computer as is selected for the SCS, the same LANs for SSTF as for SCS, and the same Instructor

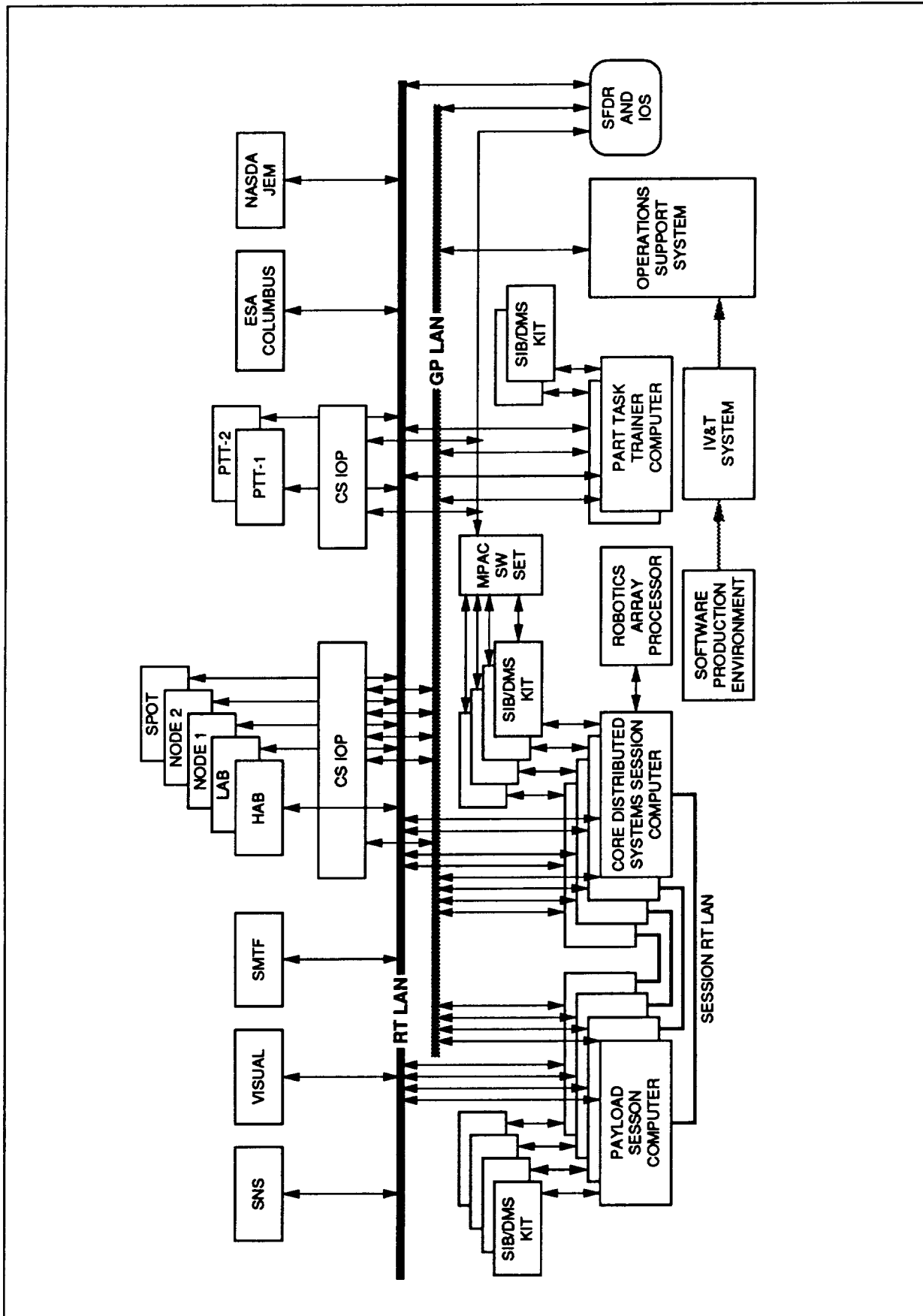


Figure 2. SSTF Systems Architecture

Operator Station (IOS) for the SSTF as for SCS. Since the SSTF and SCS designs are scheduled to be developed in parallel, the SSTF designers will not be able to simply copy the SCS for the payload portion of the SSTF. A good alternate design strategy is to follow SSE standards in selecting hardware and software. Where SSE has not specified hardware, select a common COTS product. The GP LAN will probably be Ethernet.

Another very important consideration is software compatibility. For simulation control, the simulation modes must be matched for the SSTF and PTC. Also, interfaces between software communicating over the RT LAN must be worked to be compatible. Another compatibility factor is that the requirements for what the payload models must simulate are different between the SSTF and PTC. For example, in SSTF Whole Station Training there is concern with things like payload venting that affect the SSF attitude, where as the PTC has no known need for a payload model to simulate venting.

## **2.2 DMS KITS**

During the earliest phases of the SCS Study, a ground rule was baselined that the PTC would make maximum practical use of flight software. This decision was based on the Program Definition and Requirements Document (PDRD) SSP 30000 requirement that "High fidelity training systems shall have the capability to use flight software" and lessons learned from the SpaceLab Payload Crew Training Complex (PCTC) relative to the impacts of simulating flight software in the training environment. The SCS requirements and conceptual designs were then based on the underlying assumption that both Space Station systems (e.g., C&T, OMA, DMS) flight software as well as payload flight software would be executed in the SCS supported by simulations. The SCS Study Phase One SDF Technical Demonstration showed the feasibility of this approach. Additional requirements were placed upon the SCS to support the use of flight equivalent or prototype payload hardware/software combinations in the training environment (per the PDRD section 4).

At this point in the program, only DMS Kits offer the capabilities to execute flight software in a ground simulation environment. The DMS Kits consist of Functionally Equivalent Units (FEUs) of the DMS components along with functionally equivalent busses/networks and a Simulation Interface Buffer (SIB). No other environment has to date been identified to support the execution of flight software in an environment realistic enough to support training. Therefore, adequate DMS Kit functionality to support training coupled with a sufficient allocation of Kits and components to the SCS is absolutely central to the development of a workable SCS design that fulfills the requirements as stated above.

The DMS Kit CEI Specification along with a subset of more detailed requirements was reviewed at the recent DMS PDR3. With minor exceptions that have been worked through the RID process, DMS Kit functionality will adequately support PTC/SCS requirements. However, the allocation of Kits and FEU components to the PTC is a matter of critical concern. A PTC requirement for 8 DMS Kits of varying composition (directly related to the intended Kit use - module trainer or part-task trainer) was submitted to the program. This number of Kits and required composition represented the best estimate - based on extensive training flow analysis - of the

minimum capability required for the SCS to fulfill the training requirements. Significant reduction in the PTC DMS Kit allocation from the original requirements is considered to be a major design driver on the SCS.

The SCS requirement that payload simulators (hardware and software) be directly portable from Part-Task Trainers to Module Trainers to Consolidated Trainers to the SSTF is critical to minimizing simulator development costs. If the DMS Kit allocations are reduced such that some trainers (i.e., Part-Task Trainers) have no DMS Kit support, then payload software can not be used in that part of the PTC. If payload software can't be used, then payload simulators would be totally comprised of a software simulation (of both payload hardware and software) combined with appropriate C&D hardware mockups. This is equivalent to current practice in the PCTC. DMS Kits would only be used to execute system flight software. If the Kits are utilized purely for the execution of system flight software, the use of any Kits in the PTC is questionable due to the relationship between DMS Kit cost and the benefits derived from system flight software execution.

### 2.3 SIB

The Simulation Interface Buffer (SIB) is a key component of the DMS Kits. The SIB provides connectivity from the FEU DMS processors to the simulation host computer. It will provide capabilities to monitor all bus/network traffic on the local/global busses as well as simulate missing nodes on the networks. Capabilities for DMS fault insertion (e.g., lost messages, transmission errors) will also be provided.

Until January, 1990, design responsibility for the SIB resided in the Lockheed SSE contract. In January, this responsibility was shifted to WP02/MDSSC as a part of the Integration, Test, and Verification Environment (ITVE). IBM has assumed responsibility for SIB design under subcontract to MDSSC. At the time of the design transition, SSE had recently completed a SIB Detailed Requirements Review. The requirements that were reviewed at that point adequately fulfilled the needs of the PTC with few exceptions. No commitment has been made by WP02 to use this set of requirements as formal inputs to the IBM SIB requirements specifications. It is expected that the IBM SIB requirements and design will be based on the existing IBM SIB prototype. Therefore, SCS participation in upcoming reviews of SIB requirements and design is critical due to the unwillingness of WP02 to consider overall program needs in the SIB requirements analysis process.

Two significant drivers on the SCS design may be expected to materialize in the formal SIB documentation. First, the SIB is expected to interface with SSE-defined host computers (Architecture A - DEC Vax and Architecture B - IBM 3090 family). This interface is a point-to-point interface from the SIB directly to the host machine. No network interface is expected to be provided without significant cost impacts. Additionally, the Contract End Item Specification for DMS Kits (DR SY-06.1, March 1990) specifies a SIB-to-Host interface speed of 5 Megabytes (40 Megabits) per second, and a burst rate of 6.7 Megabytes (53.6 Megabits) per second. The SIB is expected to be a device with minimal intelligence. The host computer should be expected to carry most of the processing load for message construction, data buffer sorting, data logging, and several other functions that SSE had originally intended to be resident in the SIB.

## **2.4 OMA**

The Operations Management Application (OMA) is the highest tier of onboard command and control software. The OMA is expected to be present in the SCS either as actual flight software executing in a DMS Kit Standard Data Processor (SDP) or as a simulation executing in the host computer. To support the execution of the OMA flight software, simulations of other OMA interfaces will be required (e.g., other SS systems and the OMGA). In either case, the OMA is not considered to be a significant SCS design driver.

## **2.5 SSE/ITVE**

In the original SSE contract, Lockheed was given responsibility for providing to the program software development tools, rules, and procedures along with the simulation execution support environment (including the SIB design as discussed above). The development of the simulation execution support environment was shifted to WP02/MDSSC as a part of the ITVE. SSE has retained the responsibility for the provision of software development tools, rules, and procedures. The SSE workstation and tool selections therefore still impose design constraints on the SCS from a software development support standpoint.

At the present time the ITVE's charter is to support integration and verification of work package flight software. Specific support for other functions is currently outside the scope of ITVE. Therefore, WP02 does not plan to respond to any specific requirements from facilities such as the PTC but the PTC may use the ITVE products "as is". Even with these constraints, certain portions of the ITVE software may be quite useful in the SCS if the SCS design is engineered to accommodate them. This software includes SIB interface, simulation configuration, simulation executive, simulation data base construction/access, and data logging/analysis. The fact that the ITVE software is targeted to the SSE-defined Vax and IBM computers is an additional SCS design driver.

## **2.6 SIMULATION STANDARDS**

### **2.6.1 Simulation Control Method**

The ITVE is expected to provide a simulation executive that allows for cyclic execution of simulation models and a demand execution mode. The models will be bound to the executive and called as procedures by the executive task. A set of simulation interface services will allow the simulations to access and write data into a simulation object data base which is roughly analogous to the flight Runtime Object Data Base (RODB).

The ITVE will define interface standards both for the simulation executive interface as well as the interface to the simulation object data base. These interface standards may be considered as ICDs for the simulations that will execute in the ITVE and as such will be the de facto interface standard for all program simulations that have portability as a requirement. If the SCS makes use of the ITVE simulation executive, simulation interface services, and other ITVE software, obviously this standard

interface will be supported. Even if the SCS forgoes use of ITVE software, the design of an SCS simulation controller should implement the ITVE-defined interface standard to allow the use of simulations developed for execution in the ITVE.

### **2.6.2 Simulation Modes**

The ITVE simulation executive is expected to support all simulation modes required by the SCS. These modes include stop, start, pause (freeze), checkpoint (datastore), restart (reset), and stepahead.

## **2.7 HARDWARE AND SOFTWARE STANDARDS**

From the above discussions, and the work done in the SCS Study Phase one, it is clear that standardization of hardware and software in the PTC/SCS has many benefits. The PDRD states "The training program shall attain as much commonality as is practical between media, the curriculum, and training facilities."



### **3.0    PTC/SCS ARCHITECTURE TRADEOFFS**

As a result of the Langley Configuration-Budget Review (CBR), there were over 400 changes in the system. The CBR process placed great emphasis on lowering costs and holding to schedules. In order to evaluate the CBR affect on SCS, and facilitate future potential changes, PTC/SCS architectural tradeoffs were quantified and evaluated. This process of architectural tradeoffs was needed to allow us to define the most cost effective PTC/SCS baseline solution. Results of this effort are presented in this section.

#### **3.1    COMMON ARCHITECTURAL ELEMENTS**

These consist of hardware and software needed to meet the PTC/SCS requirements.

##### **3.1.1    Software Architecture**

Following is the list of software required for and supported by the PTC/SCS. The software is grouped by category to ease discussions and to aid in the graphic presentation of the hardware (with associated software) in the next section (3.1.2).

#### **Analysis Support**

Data Analysis - Provides the capability to retrieve and analyze data that was logged during a training simulation session. The software will support reduction of only those data records selected by the user and allow format definition for report generation.

Data Logging - Provides the capability to log various data records produced during a simulation run with time tagging capability. This function will support the recording of all or selective data generated during a training session.

Training Analysis - Assists the instructors in evaluating all training requirements, materials, and scenario development in advance of performing the training.

Training Response Capture - This software function maintains a history of the student responses during a training session. The response will be tied to training session events to support later evaluation of the student.

Training Result Analysis - Evaluates the training session responses of the student after the training session based on the analysis criteria which can be input by the instructor. This function provides for report generation based on instructor specification and transfer of data to the training management function.

#### **CBT**

Authoring Software - The software system that provides the capability to develop courseware specific to a certain payload or increment of payloads. This software

CBT allows the instructor to define the training script/scenario and associate the scenario with graphics, audio, video, data, and expected responses.

Courseware - The actual CBT software specific to a certain payload or increment of payloads that allows introductory or tutorial training without instructor intervention. This includes both question/answer type training sessions and selected interface prototypes with interactive capabilities.

CBT Control Software - This software provides the interactive user interface, control of data, audio, and video components, and collection and analysis of student responses.

### **Development Support**

C&D Panel Development - CAD/CAM system to support the design of the hardware panels.

Crew Interface Prototyping - This function supports the rapid prototyping of the crew interface (MPAC displays, C&D Panels, etc.) to support the simulation developers investigation of requirements and to possibly support early training sessions. The crew interface prototype must conform to the USE standards.

Developer Interface Functions - Software to supply the user interface for the SCS developers to interact with development tools and other system software.

Primary Instruction Development - Support for the generation of instruction material including specification of curricula, classroom syllabi, course outlines, lesson summaries, etc. This function also supports the development of training objectives, selection of methods/media, development of the instructional plan, experiment overview, and the simulator approach.

Training Requirements Development - Tools to support the requirements definition for payload training and development of associated training sessions requirements.

Scenario Development - This software allows the instructor to generate scenarios to support particular training sessions. An interface will be provided to easily define the configuration and expected training steps.

Software Development - This function provides the capabilities to support the requirements/design/code development for the SCS and simulation software. These capabilities support the initial development, the continued simulator development, and the maintenance/upgrade efforts. This will be an integrated set of tools which provides the following:

CASE

APSE

Editor

Compiler

Linker  
On-line debugger  
Model Prototyping Tool

### **Flight Software**

**C&T Software** - This is the SSF software that supports C&T.

**DMS Software** - This is the SSF DMS software which consists of the following functions:

Data Storage and Retrieval  
MODB Manager  
Network O/S Manager (NOS)  
O/S Ada Real Time Environment (RTE)  
Standard Services  
System Manager  
User Support Environment (USE)

**OMA Software** - This is the SSF on-board operations management software which consists of three levels:

Tier I - Station Management  
Tier II - Element Management  
Tier III - Rack Management

**Payload Software** - The actual payload flight software.

### **Ground Support Equipment**

**GSE Control** - This function controls all hardware which support the simulation/training session. This hardware includes the ground support equipment which provides operational needs for equipment within the PTC (power, coolant, etc.) or supplies stimuli to flight equivalent hardware. This function supports all necessary interfaces with real/prototype payload hardware and the DMS kits.

**Health and Status** - Monitors the status information on all SCS equipment involved in the training session. This compiled information can be viewed by operations personnel for recovery purposes.

### **PTC Training/Operations Management**

**Facility Scheduler** - Provides the tools for the scheduling of the resources of the PTC to support the varied training sessions within the PTC (concurrent sessions schedules, maintenance schedules, upgrade schedules, etc.). This software will

also allow the incorporation of additional scheduling constraints of external resources to support scheduling with involvement of external facilities.

**General Purpose Tools** - This category of software provides general tools for the support of administrative activities in the PTC. These include word processors, briefing chart generation support, spreadsheets, database management, etc.

**PTC Configuration Management** - This function provides the management mechanisms for control of all hardware/software components in the SCS and associated documentation. The mechanisms include the capabilities to identify problems and modifications and impacts to related areas. The function also provides the history database of versions, facility utilization, and all related data.

**Training Database** - Provides the capability to organize experiment and other data into a database in terms of mission purpose, major subsystems and components, operational policies and procedures, personnel responsibility, etc. This function will also provide the capability to analyze the data in the data base and identify all tasks necessary to operate, maintain, and control the experiment.

**Training Management** - This software supports management of the students as they proceed through the various training phases. The function provides the record keeping on individual students and supports the scheduling of each student's training activities. The transfer of training records to TMIS is supported.

**SSF/Payload Database** - Provides associated SSF and payload data that is required for SCS development of simulators, tests, training scenarios, etc.

### **Session Management Functions**

**Configuration and Setup** - This function allows the SCS operations personnel to specify a configuration which includes the necessary hardware and software to support a particular training session. The software provides the capability to automate the creation of a run-time configuration file based on simulator configuration data and training plans. This function will automatically initialize the proper software simulation configuration. The extraction of setup and configuration data from crew procedures will also be supported.

**Instructor Interface** - Provides an interactive mechanism for the instructor to monitor the training sessions and supply on-line control inputs for a session.

**Network Management** - This function controls all the network interfaces throughout the SCS and monitors the network traffic. This software supports the message transfer for distributed operations during all modes of SCS operations.

**Operating System** - This function consists of the operating systems for each processor in the SCS system. This software incorporates the device drivers necessary to support the hardware interfaces to all peripherals and other support equipment.

**PTC External Communications** - This function controls the real-time distribution of data (video, audio, CORE LAN data, Payload LAN data) to interfaces with external facilities such as the POIC, MPS, PI facility (UOF), etc. The interfaces for non real-time data transfer to external system such as TMIS, SSTF, etc. will also be supported. This software controls and monitors the hardware that supports these external interfaces.

**SCS Executive** - Controls the software simulation configuration setup through management of the simulator incorporation (which simulators with what fidelity) for the specified training session. This software ensure that a specific training or test session is configured with the proper version of the software. This function controls the system modes (standard operations, trainee absent, and preventive maintenance) for the SCS. Receipt of non-real time training and simulation session data is also supported.

**Session Readiness Test** - Provides a high level readiness check of all elements required for a particular training session.

### **Simulation Executive Functions**

**Simulation Executive** - This software controls the order of model execution, supports the internal interfacing between models, supports the external interfaces to other software functions, and controls the simulation modes (run, stop, restart, etc.). The collection of simulation execution metrics is also supported.

**Test Executive** - Controls the execution of test procedures to support the testing of simulation software by SCS developers and the IT&V personnel. This function provides an interface for test procedure definition. Proper delays and interactions with the simulation executive will provide execution of procedure steps. This software will support timeline verification, crew procedure verification, trainee absent mode and provide any specific features necessary to support test.

**Training Executive** - Controls the execution of a scenario during a training session through interaction with student, instructor, external facility inputs and the simulation executive. A rule-based evaluation of student responses can be performed in real-time which can support the modification of a scenario based on student responses. This software supports insertions of faults during a scenario. The automatic generation of expected student responses will be provided to support the trainee absent mode. This software will support timeline verification, crew procedure verification, trainee absent mode and provides any specific features necessary to support training.

### **Simulations**

**DMS** - Required or trainer with no DMS kits.

**Data Storage and Retrieval** - Models the file manipulation functions necessary to support payload training.

**MODB Manager** - Model simulates the MODB functions necessary to support the payload training. The function will allow the definition of new objects that can be incorporated into a new RODB for payload simulation.

**Network O/S Management (NOS)** - Model simulates the DMS network aspects necessary to support payload training.

**O/S Ada Real Time Environment (RTE)** - Modeling of a small portion of the RTE may be necessary to provide the transparent interfaces from application to application when the DMS is simulated and real payload software is present.

**Standard Services** - This functions simulates the runtime management of RODB objects necessary to support payload training. This software performs the reading and writing of attributes, the reading and writing of commands on objects, and the reporting of events when object attributes violate predefined limitations.

**System Manager** - This software simulates the DMS system manager functions necessary to support payload training. This function includes the startup and shutdown of DMS nodes and the monitoring and reporting of DMS errors, faults, overloads, and anomalies.

**User Support Environment** - The user support environment must be simulated to the degree necessary to support payload training. This function will provide the user interface services to simulate the MPAC displays.

## **Environment Models**

Various models which simulate the environmental conditions which will effect the SSF systems and payloads. Many of these models will support the GN&C system simulation. The models include the following:

- Aerodynamics model
- Atmosphere density model
- Gravitational forces model
- Lunar position and phase
- Magnetic field model
- Mass properties models
- Plasma effects model
- Rotating earth model
- Solar position model (orbital sunrise/sunset)
- South Atlantic anomaly model
- Station dynamics model
- Thruster firing model

## Zone of Exclusion (ZOE) model

### **Ground Systems**

**Payload Short Term Plan Generation** - This function provides the capability to generate an STP for the payload(s) in a training session. This software is not intended to provide the capability of SSF STP generation, but could be a subset of that software. This is expected to be provided by MPS system.

**AFACTS model** - Provides the simulation of the Onboard Short Term Plan generation to support the payload operations training. This software may be a subset of the AFACTS which is expected to be developed for use in the SSCC. Assume this runs on POIC computers as part of the Mission Planning System. Plan to use MPS for this capability.

### **International Partners**

**C&D Panel** - Software required to drive the C&D panels in support of training exercises. This software will control the C&D panels in response to crew actions or data from payload simulations.

**JEM/Columbus System models** - Provides the simulation of basic interface data between the JEM/Columbus systems and the JEM Lab. This function includes the International Partner system models required to support training on U.S. sponsored payloads.

**JEM Exposed Facility System models** - Provides the simulation of basic interface data between the JEM Exposed Facility system and the JEM Lab. This function will include the JEM system models which support payload commanding and payload health and safety data acquisition for U.S. sponsored payloads.

**JEM Pointing System** - This software simulates the functions of the JEM pointing system and responds to operator commands realistically enough to support training for the JEM pointing system itself and the payloads attached to it.

### **Payload Support Equipment (P/L SE)**

**Attached Payload Accommodation Equipment (APAE) Pointing Systems** - Provides the simulation of the interactions between the pointing systems and the modeled or flight equivalent payload simulation. This model also produces all necessary equipment status to support other SSF simulations.

**Attached Payload Accommodation Equipment (APAE) Systems** - Provides the simulation of the interactions of accommodation equipment with the associated payload model or payload flight software. This software provides the appropriate equipment status information to support other SSF simulations.

**C&D Panel** - Software required to drive the C&D panels in support of training exercises. This software will control the C&D panels in response to crew actions or data from payload simulations.

## **General Lab Support Facilities**

**Life Science Glovebox** - Model simulates command, control, health status and data forwarding between the LSG and the rack level processors.

**Materials Processing Science Glovebox** - Model simulates start-up and normal and emergency shutdown. Functions provided also include system monitor and control including cabinet/airlock pressure/temperature/doors, filter and circulation fans, air quality and flow rate, access to FMS, NO<sub>2</sub>, UPW, particle counter, and clean-up and transfer in/out.

**Materials Science Workstation/Lab. Science Workbench** - The workstation provides step by step procedures for conducting ORU and experiments maintenance. This model of the workstation simulates command, control, health status, and data forwarding between the MWS/LSW and rack level processors. Functions provided include monitor voltage, door interlock open/close and filter pressure data. Also included are command of blower motors, vent valves, and door enable.

### **Payload Support System (PSS)**

**Centrifuge** - This model will simulate the functions of the US Lab centrifuge and respond to operator commands realistically enough to support training for the centrifuge itself and the payloads processed within the centrifuge.

**Furnace** - This model simulates the functions of the US Lab materials furnace and responds to operator commands realistically enough to support training for the furnace itself and the payloads processed within the furnace.

**Optical Work Bench** - Simulates the functions of the US Lab flight article realistically enough to provide training for the work bench itself and for the manifested payloads that utilize the work bench. The model simulates image processing from impingement of the image upon the truss mounted large pointing mirror through reduction of the optical measurements to digital outputs.

**U.S. Lab Pointing System model** - Simulates the functions of the Instrument Pointing System or its SSF functional equivalent. The model will respond to commands realistically enough to support training for the IPS itself and payloads mounted on the system.

### **Process Materials Management Subsystem (PMMS)** - Functions simulated include:

- 1) model of gaseous NO<sub>2</sub> distribution to the user facilities and laboratory equipment
- 2) Vacuum Vent system model which simulates vacuum of non-hazardous waste gas from the US Lab user facilities and provides command, control, and health and status data



- 3) Ultra Pure Water system model which simulates the provision of ultra pure water to payloads and lab equipment.

### **Payload Models**

Generic Simulator - Used to provide early payload training for the crew in the event that user payload models are not available. Also, used as a simple driver to test the payload-to-PTC interface.

Payload - Flight Equivalent - This simulation requires flight equivalent hardware to allow execution of the payload flight software. This function will provide simulation of payload equipment/instruments that are not available in the PTC to support the stimulation of the flight equivalent software.

Payload Models - These models provide a full simulation of the payload including the flight software and hardware.

Video - Payload Image Generation - The SCS software which generates video images or graphical representations of the payload experiment to the student. This software provides a standard interface to payload simulators for manipulation of the images.

### **CORE Systems**

Audio - This software controls the audio components in the internal audio system of the IAV simulator and can support simulation of both the intra-station and ground communications.

C&D Panel - Software required to drive the C&D panels in support of training exercises. This software will control the C&D panels in response to crew actions or data from payload simulations.

Caution and Warning - Provides the simulation of C&W functions as necessary to support payload training. This software will generate appropriate system messages and alarms via panels and MPAC displays.

Communication and Tracking (C&T) - Model simulates the onboard C&T system to a level required to support payload training including PTC-to-POIC integrated training sessions and interface requirements. Functions simulated include space-to-ground communications, high rate patch panel, high rate data recorder, voice recognition/synthesis, and interface to MPACs and core systems.

### **Environmental Control Life Support System (ECLSS) models**

Air Revitalization System (ARS) - Simulates an interface to the payload manager software and the specific rack control manager.

Atmosphere Control & Supply (ACS) - Simulates an interface to the payload manager software and the specific rack control manager.

Fire Detection and Suppression (FDS) - Simulates an interface to the payload training whenever payload procedures utilize the flight FDS system.

Temperature & Humidity Control (THC) - Simulates a interface to the payload manager software and the specific rack control manager.

Electrical Power System (EPS) - Functions simulated include rack controller functions such as monitor or amps measurements, on/off status, trip status, power in/off, and reset commands.

Fluid Management System (FMS) - The simulation provides the basic interface to support the control and monitoring necessary to support the payload training.

Guidance, Navigation, and Control (GN&C) - Model simulates the onboard system to the extent required to support payload training. Functions simulated include computation of star position with respect to the SSF coordinate frame, model SSF orientation and acceleration using star tracker and idealized gyro models.

Internal Thermal Control (ITC) - Functions simulated provide active thermal control services to customer/experiments and General Lab Support Facilities in the US Lab. Functions simulated in the PTC include:

- 1) Perform initialization, shutdown and system loop test.
- 2) System monitor and control which includes rack flow control, pump package, energy acquisition and transfer and determination of system flow rates, including response to rack flow anomalies.

OMA (Tier I) - Provides the interface from the OMA to the element manager for those actions that can effect the payload operation. Only required in trainers with no DMS kits.

US Lab Element Manager (Tier II) - Provides the interface from the element manager to the rack manager for those actions that can effect the payload operation. Only required in trainers with no DMS kits.

US Lab Rack Manager (Tier III) - Provides the interface from the rack manager to the payload simulations for those actions that can effect the payload operations. Only required in trainers with no DMS kits.

Video - This software controls the video components in the internal video system of the IAV simulator and can support simulation of both the intra-station and ground communications.

### **3.1.2. Hardware Architecture**

Based on the detailed study of the three designs recommended in Volume 3 of the SCS Study Report, "Refined Conceptual Design Report" and on the considerations

discussed above in section 2.1 "SSTF Design" and 2.3 "SIB", the Local Host design evolved as the most suitable to meet the needs of the PTC/SCS. Consequently, it was selected as the initial SCS baseline for further assessment of issues surrounding the design and implementation of the PTC/SCS. As defined in that report for the Local Host design, a separate host computer is dedicated to each major trainer and facility. The design was formulated to:

- use DMS kits and other SSF compatible components in all trainers
- accept flight equivalent payload hardware and
- software without significant modification
- isolate and minimize the real time traffic loading on
- the PTC/SCS LAN
- interface directly with SSF support systems,
- development systems, and communications systems.
- provide for simulation of payloads, DMS, and the environment on the same general purpose host

### **3.1.2.1 System Design**

A top level view of the selected PTC/SCS design is shown in Figure 3.1-1. Details of this design are addressed in the following paragraphs.

#### **3.1.2.1.1 General Description**

The architecture of the SCS baseline is distinguished by the fact that a local host computer with LAN interconnectivity is dedicated to each major trainer and facility. The following characteristics summarize the baseline Local Host design:

- A local host is the baseline provided for each trainer and facility, with characteristics and performance specifically tailored to the particular type of trainer or facility.
- Connectivity within a trainer is provided by the Core LAN and Payload LAN
- Connectivity between each trainer and support facility is provided by the SCS LAN
- Connectivity to external facilities is provided by telemetry and telecommunications
- Trainer configuration is controlled by instructor work stations attached to the SCS LAN
- A combination of both DMS supported trainers and non-DMS trainers are selected to provide the best engineering design and value.

Each of the above design features are discussed in later sections of this chapter.

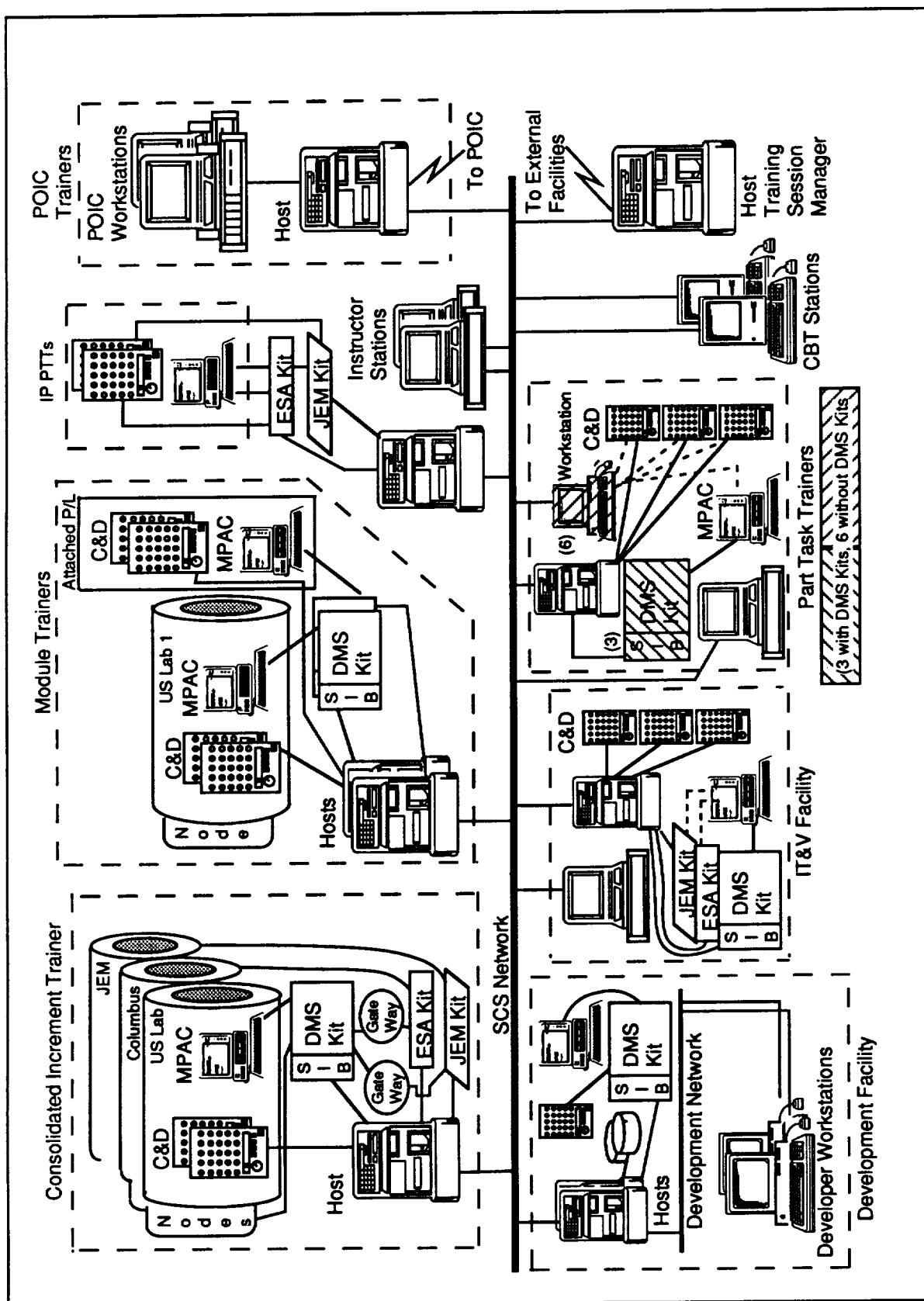


Figure 3.1-1 Local Host Overview

### **3.1.2.1.2 Network Architecture**

The baseline design integrates the PTC/SCS using four types of LANs:

- 1) The SCS LAN which ties the separate facilities and trainers to central management and communications resources
- 2) The Core LAN
- 3) The Payload LAN within each DMS kit based trainer
- 4) The local LANs within each facility that connect workstations and terminals to their respective file servers

The Core LAN and Payload LAN consist of the FDDI LAN, concentrators, and NOS, included as part of the DMS Kit and, minimally, are functionally equivalent to their SSF flight counterpart.

The traffic on the SCS LAN consists predominantly of file transfers and message traffic between the Session Management Functions (formerly the Training Session Manager), Instructor Workstations, and Trainer Host computers. A 16 Mbps Token Ring LAN has the capability to perform this function.

The PTC/SCS support facilities and POIC trainers also connect to the SCS Network. In the case of the POIC Trainers, it should be noted that the telemetry feed is handled by a separate communications system and does not enter onto the SCS LAN.

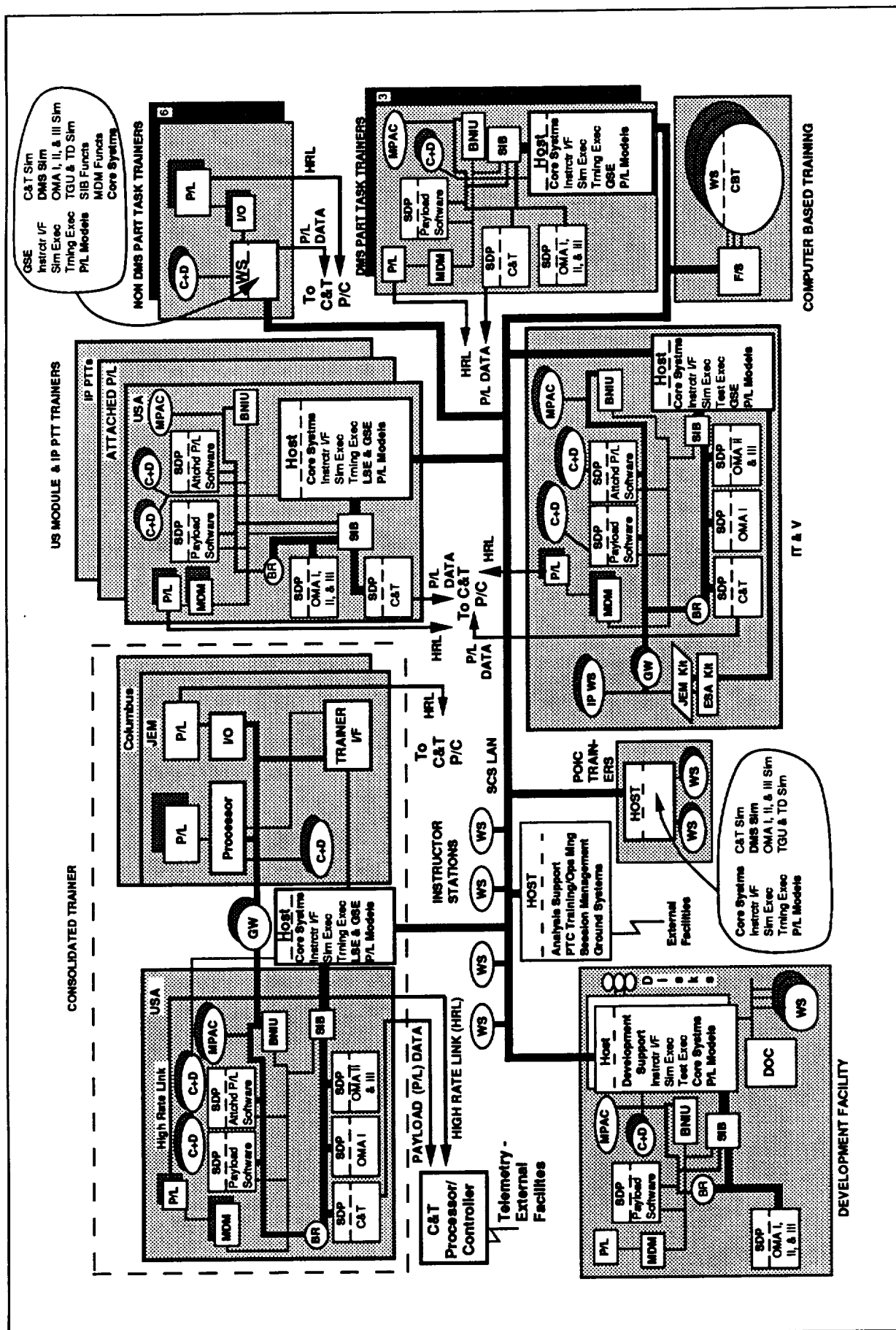
The use of local LANs within the CBT Facility and Development Facility support the prescribed workstation and file server configurations. The LANs support relatively low traffic loads of large, and acceptably queued, file transfers. Either a 16 Mbps Token Ring or a 10 Mbps Ethernet LAN are acceptable for this function.

### **3.1.2.2 Trainer Design**

The Consolidated, Module, and DMS kit based Part Task Trainers share the same essential architecture throughout the PTC/SCS design. Figure 3.1-2 diagrams the representative Module Trainer architecture showing the DMS Kit components and the allocation of the software functions discussed in Section 3.1.1

Replication of the Space Station DMS architecture in these trainers with DMS Kits offers the benefits discussed in the previous studies. The approach also ensures that: 1) flight equivalent payloads will operate within the trainer; 2) payload models developed by the PTC for training are easily transportable to the SSTF; and 3) Core systems models developed for other Space Station requirements can be used with the trainers.

Provision for generation and transmission of High Rate Science Data via a High Rate Link (HRL) is provided for use by any payload. Dynamic data generation up to 100 Mbps is supported.



**Figure 3.1-2 Top Level View of Local Host Design**

### **3.1.2.2.1 Host Architecture**

Each DMS kit based trainer relies on a dedicated local host -- connected to its SIB through its proprietary channel attachment -- to support all real time simulation functions not provided within the DMS-SIB complement. The Trainer Host provides the processing for: 1) the simulation executive governing real time functions; 2) configuration, setup, and initialization support to the Session Management Functions; 3) payload, core, and environment model execution; 4) audio/video control; 5) data base access 6) data/event recording; 7) device stimulation and GSE control; 8) local diagnostics; and 9) DMS kit control.

The Training and Simulation Executives synchronize scenario, payload model, core model, and data base execution in the host with DMS/OMA software execution in DMS Kit SDPs. Synchronization with, and control of, the DMS complement is mediated through the SIB. The executives monitor system status, simulation session status, and student actions, and allow student console and panel views to be repeated on the Instructor Console. Through the SIB, the Simulation Executive controls trainer operation including start, stop, step, freeze, sequence, and replay modes. It also synchronizes the interface between simulation execution and peripheral devices including the Audio and Video Systems and payload C&D panels. The Training Executive reports system configuration and simulation session status to the Session Manager.

The Trainer Host may also execute payload simulations used in lieu of actual flight equivalent payloads when so required. Payload simulations involve the simulation model software developed for that payload experiment and the C&D panel configured accordingly. The software may be executed on the host to which the C&D panel is attached. If a payload normally generates video, the model based generation is controlled by the host using a processor attached video adapter. The host also controls other audio and video generated or replayed by the Audio and Video System.

The Trainer Host communicates with the SIB and its attached DMS components via a proprietary high speed bus channel link. It communicates with the Training Session Manager and other PTC/SCS training support facilities via the SCS Network.

The OMA and network operating system (NOS) software furnished with the DMS Kit are hosted on one or more DMS SDPs (or possibly in the BNIUs). Flight equivalent payload software may also run in SDPs or EDP-4s within other DMS components. The SIB provides the necessary platform and software to effect control and synchronization of the DMS configuration.

### **3.1.2.2.2 Model Representations**

#### **3.1.2.2.2.1 Payload Representation**

The payload representations consist of either the flight equivalent payload hardware and software or a software payload model and associated control and display hardware. The flight equivalent article includes the DMS compatible instrument, a flight equivalent Control and Display panel, and associated flight

equivalent software. The software payload models consist of software that runs, under the simulation executive, either on the trainer host or in a DMS component processor.

### *Flight Equivalent Payload*

The flight equivalent payload consists of rack mounted or attached instrument chassis, an integral C&D panel, application software, and perhaps peripheral equipment. The payload may also utilize associated lab facility hardware provided to support related experiments.

Flight equivalent payloads connect to the DMS through an MDM, NIU, or a BIA.

#### 3.1.2.2.2.2 Payload Stimulation

Flight equivalent payloads are stimulated through effects experienced in orbit. This stimulation includes direct sensor activation, effector feedback, signal injection, and external forces to emulate the control and ambient effects on the experiment of the space station's environment. The payload stimulator is an intelligent controller receiving data from the Core and environment models. The stimulator connects to the host I/O port and to the flight equivalent hardware directly and/or through the DMS Local Bus. Within each trainer, the payload stimulators may also be responsible for controlling or emulating some of the necessary GSE services to sustain the payload.

Where flight equivalent payloads are employed, a payload stimulator is required to provide sensor excitation and other ambient effects to the payload that would normally occur in flight. The stimulator is driven by simulation models and data bases which represent the Space Station environment and crew actions. The payload stimulators represent with some approximation those stimuli critically affecting payload operation and performance.

For control purposes, the payload stimulator can be integrated into a trainer using three different interfaces such that:

- A payload stimulator connects to a trainer host directly using standard I/O port (RS232 or SCSI).
- A payload stimulator attaches to the DMS Local Bus (and connects to the Trainer Host through the SIB).
- A payload stimulator attaches with a processor based controller and network interface directly to the trainer's network (Payload LAN, or Trainer LAN - if non-DMS trainer).

#### 3.1.2.2.2.3 Payload Panels

The payload C&D panels associated with individual experiments are functional equivalents of flight hardware positioned realistically in a trainer's lab mockup. Two panel types may be utilized: 1) (normally) a hardware replication of the flight payload panel; and 2) a generic reconfigurable terminal system i.e. a "virtual panel". These



panels are generally connected directly to the host. In addition to the panels, the SCS baseline supports other experiment devices and associated lab support equipment furnished within the physical lab mockup through the SIB and MDMs.

#### 3.1.2.2.4 Core Systems Representation

Core systems are represented in two ways: one as simulation models running on the Trainer Host and, for other functions, as flight equivalent Core software running on the Core DMS SDPs from DMS kits. For purposes of PTC/SCS baseline design, Core systems are treated as representing all space station systems that affect payload operations or performance, other than those encompassed by the payload DMS representation. Environment models and data bases to represent the dynamic space and space station environments are also included in the Core systems category.

The baseline C&T model provides formatted uplink/downlink communications containing SSF data from the: 1) Payload LAN; 2) Core systems LAN; 3) payload High Rate Link; and 4) audio/video sources. Payload LAN data and High Rate Link data can be obtained from both actual flight equivalent payloads and payload simulation models. The C&T model uses dedicated hardware to generate the telemetry data stream necessary to feed the POIC Trainers and the POIC.

This C&T telemetry system processor/controller is shared among the lab trainers through a patch panel which routes one trainer's C&T-bound output to the processor/controller. The output of the C&T is an SSF compatible telemetry data stream that can be received by the POIC. The simulator inputs to the C&T include HRL, payload LAN, Core LAN, and host I/O feeds of science and command/status data. The C&T implementation also supports SSF audio/video communication streams. The C&T implementation will support receipt of commands from the POIC.

#### 3.1.2.2.5 Crew Interface Representation

The two primary interfaces for monitoring and control of the payloads are the rack mounted experiment's attached C&D panel and the lab's multipurpose application console (MPAC). Additional payload features such as mechanical controls are considered part of the lab-payload physical mockup and involve minimal interfacing to the SCS.

##### *3.1.2.2.5.1 C & D Panels*

The C&D panel consists of switches and indicators that provide payload control and display of information. When flight equivalent payloads are used, the associated C&D panel is integral to the hardware. Alternatively, when payloads are simulated with software models, the associated C&D panel appears in two versions. One is a close replication of the actual panel hardware used on the flight payload. This is a custom designed piece of hardware dedicated to a particular payload experiment.

The other option uses a "virtual C&D panel" incorporating a high resolution touch sensitive graphic display and appropriate I/O interfaces to achieve a functionally accurate representation of the actual flight panel. The virtual panel can quickly be

reconfigured (re-programmed) to represent the control and display elements making up any flight payload experiment panel.

#### ***3.1.2.2.5.2 Crew Console - Multipurpose Application Consoles (MPACs)***

The basic fixed MPAC currently planned for the SSF is implemented within the DMS kit based trainer designs using the DMS Kit supplied flight equivalent MPACs attached to the Payload LAN. Representation of the DMS kit supplied portable MPAC (P-MPAC) is similarly provided with a DMS Local Bus connection. The Module Trainers have been configured with two crew consoles; the Consolidated Trainer with two consoles in the US Lab and one each in the JEM Lab and Columbus Lab; and one console in each Part Task Trainer.

#### **3.1.2.2.6 Audio/Video Systems Representation**

The Audio and Video Systems' capabilities accommodate onboard space station lab internal communications and CCTV, audio communications with the ground, payload generated video, and computer generated imagery to simulate visual scenes and events associated with flight payload operations (such as viewing a star field). Internal PTC facility intercom is not specified as part of the PTC/SCS baseline in this document.

#### ***Audio/Video System Implementation***

Where necessary, the audio and video systems are interfaced to the C&T portion of the Core systems representation to allow audio and video data to be formatted and merged into a trainer's telemetry data stream. High Rate Link data streams are assumed to be pre-formatted and to interface directly from the payload representation to the C&T processor/controller.

The audio and video systems are implemented using standard intercom stations, CCTV cameras, tape recorders, and optical disks under computer control. Additionally, computer generated graphic imagery is provided by coprocessors or peripheral processors connecting to the trainer host.

Video is generated dynamically in response to real time Core, environment and crew interactions. Live (NTSC) video may be mixed with any generated source in real time. Fidelity of the Payload video is to be rendered computer generated imagery plus NTSC.

#### **3.1.2.2.3 DMS Components**

The flight equivalent DMS hardware and software components used to implement baseline DMS Kit based trainers are described in Section 2.2. DMS software including the Operations Management Application (OMA), Network Operating System (NOS), and the DMS Standard Services are executed in the DMS SDP. The DMS components support the connection of flight equivalent payloads to the DMS. It is assumed and has been depicted in Figure 3.1-2, that flight equivalent payloads interface to the DMS through an MDM. Provided that the payload instrument is

equipped with other interface capabilities such as a BIA or NIU, the trainer design will also accommodate these alternative modes of connection.

#### **3.1.2.2.4 Trainer Connectivity**

Trainer connectivity is implemented in varying degrees throughout the Local Host Design. The greatest connectivity (U.S. lab module to IP modules) exists within the Consolidated Trainer. All trainers are interconnected only by the SCS LAN which, in this design, is intended to carry a minimal amount of real time simulation traffic.

##### **3.1.2.2.4.1 Consolidated Trainer**

The Consolidated Trainer has three means of connectivity across its three constituent labs: 1) Core and Payload LANs; 2) common Timing Generation System and Distribution Bus (TDB); and 3) common Core models. At present, the nature of the LANs to be employed in the Columbus and JEM labs is not known. The DMS Kits incorporate gateways between the US lab and the other labs. If the Payload and Core LANs of the Columbus and JEM labs are compatible with the OSI layers 1 and 2 adopted by the FDDI protocol, the gateways may be replaced with bridges.

The Consolidated trainer relies on a common Simulation Executive hosted on a single computer to supervise all three labs. The computer hosts all payload models. Generation of the trainer's audio and video for the labs is also under the control of this host. The Columbus and JEM labs are connected to the host through an undetermined interface identified in the figures (3.1-1 and 3.1-2) as a Trainer I/F.

##### **3.1.2.2.4.2 Other Trainers**

The Module Trainers and Part Task Trainers operate independently and are only interconnected through the SCS LAN. Each trainer relies on a dedicated LAN for primary connection of its internal components. In addition to the component connectivity provided by the payload LAN for all trainers the SIB adds additional connection paths to the DMS kit based trainers.

#### **3.1.2.3 Support Facilities**

The support facilities include the Development Facility, External PTC Interfaces, POIC Trainers, IT&V Facility, CBT Stations, Training Session Manager, and central Instructor Stations. A top level view of the facilities architecture is presented in Figure 3.1-1 and a more detailed hardware and software description in Figure 3.1-2.

##### **3.1.2.3.1 Development Facility**

Since it is expected that a large percentage of the payload experiments installed in a trainer will be software simulation models, rather than flight equivalent payload hardware and software, and that at least 50% of the software models will be developed on the SCS, a substantial SCS Development Facility is required. The facility has been designed to support on the order of 100 concurrent users performing a mix of software development tasks without impinging on the SCS LAN.

The facility connects workstations and terminals (diskless workstations) to dual file servers via a local LAN. The diskless workstations are economical and will support the development function. The file servers provide common access to central code libraries, data dictionaries, batch job facilities, and configuration management tools. The workstations support the bulk of program design, code generation, compilation, and local configuration management. The dual file servers also provide the computational resource for ASCII and graphics terminals (diskless workstations) attached to the local LAN through a terminal server. These terminals support source code editing, documentation authoring, and testing tasks, as well as batch job submission. The file servers connect to the SCS LAN to permit developed software to be downloaded to the PTC/SCS trainers and other facilities.

The documentation system is implemented with COTS publishing software running on a dedicated host.

#### **3.1.2.3.2 External Interfaces**

The baseline will provides a real time interface to the POIC. This interface allows uplink/downlink data to be exchanged between the SCS and the POIC. This FDDI network provides a throughput consistent with other FDDI systems in the SCS. Improved FDDI, or multiple LANs, are expected to increase the network capacity beyond 100 Mbps to 300 Mbps.

Other facility interfaces will allow file transfers between the MPS, SSTF, and the Pls. The interfaces are implemented as gateways to appropriate wide area networks (WANs). The gateway host resides on the SCS LAN. Interfaces that must support full telemetry data streams are implemented with the host and an attached I/O processor.

#### **3.1.2.3.3 POIC Trainers**

The Payload Operations Integration Center (POIC) Trainers operate independently or in synchronization with lab trainers. Each POIC Trainer consist of a host processor and two workstations sharing the SCS LAN. The workstations serve as ground personnel stations. Instructor stations are located on the SCS LAN and are shared with other SCS trainers. The POIC trainer is connected to the SCS LAN and to an interface for the telemetry data stream. When this data stream is of moderate (100 Mbps per second) bandwidth, it may contain simulated or actual DMS Payload LAN data and High Rate Link data. Full capacity dynamic downlink data streams, however, require the telemetry system processor/controller which is linked to a comparable C&T processor fed by one of the PTC/SCS lab trainers. Audio and video signals are represented realistically in the POIC trainers with feeds from the baseline PTC/SCS Audio and Video System.

#### **3.1.2.3.4 IT&V Facility**

The IT&V Facility is used to integrate and validate, within the PTC/SCS lab trainer environment, the: 1) payload simulation models; 2) SSF systems and environment models; 3) flight equivalent hardware and software units; and 4) C&D panels. These elements are operationally tested within the DMS, Core, C&T, and

control aspects of the simulator configuration. LAN and bus monitoring capabilities and processor breakpoint capabilities are implemented within the facility using the SIB or comparable utilities. The architecture of the IT&V Facility is essentially identical to the Module Trainer architecture. The facility connection to the SCS LAN permits software modules to be downloaded from the Development Facility.

#### **3.1.2.3.5 CBT Stations and Facility**

The CBT Stations consist of interactive graphic, video, and audio capabilities implemented on a workstation running customized courseware. The facility consists of several CBT Stations connected to a file server over a local LAN. The CBT file server is connected to the SCS LAN for downloading software and courseware from the Development Facility. Provisions for local removable media including optical disk, video tape, and magnetic disk are implemented in the baseline.

#### **3.1.2.4 Simulation Control and Monitoring**

##### **3.1.2.4.1 Session Management Function (SMF)**

The Session Management Function [formerly known as the Training Session Manager (TSM)] operates as a high level system executive residing on a single host attached to the SCS LAN. The SMF communicates directly with the simulation executive programs residing on the dedicated trainer hosts. The SMF controls access to the trainers on the SCS LAN and mediates all file transfers and message traffic. While most functions like setup and initialization precede simulation session running, real time responsibilities do exist including supervision of Instructor Station requests. The Session Management Function and its host are responsible for external interface communications with other facilities.

##### **3.1.2.4.2 Instructor Stations**

The Instructor Stations are attached to the SCS LAN and communicate with the individual trainers through the training executives residing on the trainer hosts. Direct access to the training executives is granted to monitor status information and replicate the views appearing on the students' crew consoles and C&D panels. The IOS permit control of training scripts and scenarios. The stations are implemented as workstations with interfaces to the Audio and Video Systems and are represented in Figure 3.1-1 and 3.1-2.

### **3.2 Cost Drivers**

The implementation requirements and utility of the baseline PTC/SCS design are examined in this chapter in the context of a number of cost drivers. These cost drivers, concerning critical function and design alternatives for implementing the PTC/SCS, are examined in detail with particular regard to performance versus cost. This chapter provides the basis for the determination of the solutions presented in chapter 4.

The arrangement of this chapter is as follows: Each of the cost drivers is examined as a set of options, design alternatives, or, in some cases, major parameters. There is a discussion of the impact of the cost driver under four major headings: Training, System, Cost, and Comparison. The ramifications of the options on the PTC/SCS training provided are discussed in the Training section, the impacts on the PTC/SCS system design for each of the cost drivers are considered in the System section, the cost impacts are discussed in the Cost section and a summary comparison/analysis is given in the Comparison section.

The Training sections discuss the impact and implications of selecting each of the cost driver options on the fidelity, type, or amount of training.

The System portion of the SCS includes all equipment and software representing the SSF, ground and environment elements, other real time simulation training functions, the hardware and software supporting non-real time simulation training functions such as initialization, reconfiguration, record keeping, and executive control of instruction and external communications links; and support functions such as model development and test, scenario development and management, and CBT.

Generally, the table in the Comparison section of each cost driver issue selects distinctive options and contrasts the differences in their hardware and software makeup. In some cases, where it is more meaningful, the Comparison section simply summarizes the major effects of the options. The "fixed" requirements refer to those system and trainer components that comprise the completed PTC/SCS before specific payloads are installed. The "incremental" requirements refer to hardware and software components that must be developed or modified to implement training on a particular SSF increment. Primarily, the incremental change consists of introducing a set of new payloads. Where cost is based on a "unit" trainer, that is taken to mean the U.S. Lab module trainer - with a "shipset" of 43 payloads (24 concurrently active) - unless noted otherwise.

The comparison table identifies option requirements which differentially affect PTC/SCS and training implementation costs, not life cycle costs such as SCS maintenance and expansion. If these factors are impacted differentially by the options, the effect is noted in the table in the Comparison section.

Frequently, the unique components used to implement an option directly depend on other system/trainer components that must be present for the implementation to work. When these secondary or derived requirements differ between the options, they are included in the Comparison tables.

The assessments made in this section are based on overall PTC/SCS implementation cost considerations. Final selection of the best option under any particular cost driver should consider other factors such as relative risk and impact to implementation schedules. The System's potential to accommodate changes in PTC mission requirements should also be considered.

Computer platform classes are referenced in the Comparison tables by a two letter code. See Figure 3.2-1 below for an explanation of these codes. Codes do not necessarily imply implementation or use of a specific platform. Derivation of detailed performance data and the assumptions made in this process is documented in Appendix A. This Appendix is based on the work documented in the SCS Study Report - Volume 3, the "Refined Conceptual Design Report", 31 October 1989, and all the design work done by the SCS Study team during 1990.

ID	DESCRIPTION	PERFORMANCE (in MIPS)	\$/MIP (000)	EXAMPLE
SC	Super Computer	100-1000	\$10	Cray Y-MP4
MF	Main Frame	20-120	\$110	Amdahl 5990
MS	Mini-Super	50-200	\$7	Convex C240
SM	Super-Mini	30-80	\$60	DEC 9000
WS	Work Station (Engineering)	6-30	\$20	DECstation 5000
WG	Work Station (Graphics)	6-30	\$50	SGI 4D/240 GTXB
RS	RISC (Reduced Instruction Set Computing) Station	5-27.5	\$1	IBM System 6000
PC	Personal Computer (Standard)	0.5-5	\$1	IBM AT
MC	Mini-Computer	10-40	\$70	DEC 8830

**FIGURE 3.2-1 REFERENCE COMPUTER CHARACTERISTICS AND PERFORMANCE**

### **3.2.1 Type of C&D Panel Crew Interface:**

- a) custom hardware panel
- b) virtual panel

#### **Training:**

Custom hardware C&D panels will provide the highest fidelity training possible in a non-orbital environment.

Virtual panels are representations of the actual C&D panels drawn on a computer screen with a touch screen overlaid. Trainees can touch the drawing of a button or dial to interact with the panels. This technology has been investigated as part of the SCS Study, and panels that look like photographs of actual control panels are currently available off the shelf. The pictures react to touch just like the real panels, e.g. when you touch a toggle switch or push button picture, the switch or button is redrawn in real time in the flipped or pushed position. The training provided by virtual panels will never be as high a fidelity as custom hardware panels, but would be greater than medium fidelity. This might well be sufficient for some or all of the part task training for payloads. This technology is currently being used for training in part task training on avionics and other real time control simulations. Some training objectives may not be well served by virtual panels when manual dexterity or depth perception are important aspects of the crew tasks.

#### **System:**

The custom hardware panel, whether driven by the payload instrument or by a software model, will require more I/O processing (in hardware and software) than a virtual panel which has onboard intelligence to provide standard communications protocol over a SCSI or similar link.

Virtual panels would provide rapid reconfiguration to any increment since the C&D descriptions would all be data driven. The ability to quickly configure a module trainer to a specified increment could mean less module trainers may be required, i.e. one US Lab Module instead of two. Quick reconfiguration would aid in scheduling training for currently training increments. Virtual panels will require additional disk storage for reconfiguration downloads. Development utilities for the virtual panels such as object oriented shells for rapid software development can minimize PTC development resources and labor.

#### **Cost:**

Custom hardware C&D panels will likely only be provided by PIs when they are providing the complete flight equivalent payload instrument. The flight equivalent panel is also a custom construction which may or may not be provided by the PI. Due to manufacturing, hardware configuration management, and installation time, development cost can be expected to be at least an order of magnitude greater than that needed for constructing virtual panels. Estimates based on PCTC experience are;



120 hours for design and manufacture; 21 hours for documentation; 4 hours for CM, 8 hours for test; and 4 hours for installation; for a total of 157 hours per panel.

If custom hardware panels are not provided by the PIs, development of custom C&D panels with some level of functionality will require specialized development, manufacturing, and test facilities at the PTC.

The cost of a display terminal for each payload in the shipset (e.g., 43 in the U.S. lab module trainer) is amortized over the number of full change-outs of payload shipsets over the life of SSF. (Thus, if 15% of the payloads are changed out in every 90 day increment for 30 years, then final panel hardware cost per payload is the original shipset cost divided by 18 full change-outs).

The bottom line is the difference in per unit cost of the custom item versus the per unit virtual panel development time plus the per unit share of the initial cost of the PTC/SCS virtual panel development platform/shell and the fixed number of delivery platforms amortized over the total number of payloads simulated over the life of SSF (e.g., approximately 600 based on 20 per year for 30 years).

Engineering estimates indicate that a well designed virtual panel shell will permit development and test of a payload panel in about 40 man-hours.

#### Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) Custom H/W panel	1 MDM for every F/E P/L + 1 CAMAC C&D I/F for each rack + 1 CAD/CAM WS + a panel manufacturing facility	Custom panel for each P/L (157 labor hours + material)	Custom panel & F/E C&D I/F programs + CAD/CAM mechanical & electronic S/W	PI or PTC program for each C&D panel
(b) virtual panel	1 virtual panel WSs of 5 MIPS*** with 4 monitors per rack + 1 develop WS of 8 MIPS****	None (other than P/L specs from PIs)	Development toolset	40 labor hours per P/L

\*\*\* Virtual panel delivery workstation is per estimate in Section 2.6 of Appendix A.

\*\*\*\* Development workstation for virtual panels is comparable to WS in Section 2.21 of Appendix A, supporting up to 12 new payloads in 90 days

### **3.2.2 Type of MPAC Crew Interface :**

- a) flight equivalent MPAC
- b) simulated MPAC

#### Training:

Flight equivalent MPACs will provide the highest fidelity training possible in a non-orbital environment.

Simulated MPACs could range in fidelity from low - a COTS PS/2; to medium - an 80386 WS with a single display screen; to high - a complete functional copy of the flight MPAC (per the Training FCD, a "II A" fidelity simulator). While the low and medium fidelity MPACs would be useful, the fidelity for payload training at the PTC is required to be high, and thus the MPAC must look (have the same number and type of screens, hand controllers, and keyboards as a real MPAC), and these must be functionally (same colors, same menus, same timing) like real MPACs. This means option "b" considered here is a high fidelity MPAC simulator.

#### System:

The higher the MPAC fidelity, the greater the communications load will be on the SCS Trainer LAN.

If the MPAC is simulated, a common platform could be used to implement both the MPAC and the Instructor Station, resulting in more flexibility for reconfiguration and expansion.

#### Cost:

Flight equivalent MPACs are currently projected to be expensive (\$159K each) relative to COTS hardware - workstations and associated peripheral devices (extra screens and hand controllers). Software necessary to emulate/simulate the MPAC look and functions, however, will require custom development if a COTS workstation is used

A high fidelity MPAC simulator (option b) would require three 15" color flat panel displays which can window NTSC video, two hand controllers, one keyboard with keys that match the flight MPAC, and an 80386 workstation to drive these peripherals. The color flat panel displays to be used are not yet commercially available. They are being developed under a joint IBM/Toshiba effort. The DMS software would have to be modified to work on the workstation, or software written to simulate the DMS software (OS/Ada Run Time Environment, Standard Services, Data Storage and Retrieval, User Support Environment, System Management, and MODB Manager). Since the cost of this DMS software simulation would be amortized over a small number of units, and

the DMS software would be GFE to the PTC, the high fidelity MPAC simulation (b) would cost more than the flight equivalent MPACs (a).

For a medium fidelity MPAC simulator, a current midlevel workstation with graphics (15" CRT color display) plus CCTV/VCR peripherals should be sufficient hardware for fixed MPAC fidelity (meets training requirements). A window representation of the MPAC's three monitors will provide adequate "look & feel" as well as functional fidelity. Assuming that the initial simulation software development costs can be amortized over several units, the per unit cost is estimated to be roughly two thirds the cost of a flight equivalent MPAC.

A low fidelity "functional only" simulation can be achieved with a PS/2 and an 8514/A plus NTSC display for about one fourth the cost of a flight equivalent MPAC, not including required custom software. This is based on SCS Study Extension Task 5 experience.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) F/E MPAC	1 FMPAC + 1 portable per DMS trainer or facility+ 1 additional FMPAC for IT&V	None	F/E USE and other DMS system programs	None
(b) simula- tion	1 RS of 5 MIPS** + 3 flat panel displays +2 hand controllers + A-V components for each FMPAC representation + 1 Lap Top per trainer or facility	None	41 K SLOC*** emulation program + develop. toolset	None

\*\* Workstation estimate for crew interface function is based on similar designs (discussed further in Section 2.6, "Crew Interface Representation", of Appendix A)

\*\*\* Estimate is based on the assessment that the simulator will implement approximately 50% of the functions of the full space station along with code sizes, of flight equivalent USE and SM derived from S/W sizes provided in DMS SRS documents. See Paragraph 3.2.6, "Use of DMS Kits" for details.

### **3.2.3 Fidelity of Payload Models:**

- a) full functionality (Level 1 or 2 per the DMS ACD)
- b) black box functionality (Level 3 per the DMS ACD)

See Appendix B for a copy of the DMS ACD Level definitions.

#### Training:

Full payload functionality would provide the highest fidelity possible non-orbital training. The functionality must result in discernable events with which the crew (trainee) may interact; otherwise the heightened functionality is meaningless for training. Payload model update rates must be fast enough so that the trainee sees the same payload response (display, light, needle move, etc.) that would be seen on the flight payload.

Black box functionality, where the payload model responses might be table driven for example, could provide procedural training with enough fidelity to supplement the required high fidelity science training. Previous SCS Study work (Study Issues Report, 31 Oct. 1989, Issue T-6 "Fidelity of SS Experiment Simulators") based on SpaceLab PCTC experience clearly indicates that high fidelity payload simulators will be required in the PTC.

Simulation update rates also affect the fidelity of payload simulations. The appropriate update rate varies with the particular payload, SSF, or ground function/event being represented. Simulation cycles only need to be frequent enough to yield realistic input/output that is tangible to the crew (trainee) and that relates to training objectives.

#### System:

Full payload functionality will require commensurate functionality in the environment models and Core models, as well as in payload stimulation and GSE capabilities. Full payload functionality means larger software models than those required for black box functionality. Larger models mean proportionately greater required computer CPU power (MIPS) and greater central storage space and download capacity for system reconfiguration and initialization.

Full functionality has an indirect effect on operations requirements. Larger and more complex models means correspondingly longer development time, resulting in the requirement for more concurrent development and testing system capabilities.

Slower update rates provide a savings in the total MIPS required, and may allow more concurrent training sessions to be hosted on the same complement of computers.

Update rates have a secondary effect on system support. A potential effect is a larger session recording capacity (to support data logging and recovery functions). This increase is required since the capture and store rate must be increased to track

the highest simulation update rate (otherwise some short term events would be missed).

Update rates cannot be assigned if DMS kits are part of the installation. The presence of DMS Kit components and flight equivalent software in a design limits the possibility of implementing and synchronizing "local" update rates that are economical. Thus, even though training objectives may be served with a slower rate, the presence of flight equivalent DMS elements may dictate faster update rates.

#### Cost:

Complexity, in general, increases directly with model fidelity. An assumption, based on SpaceLab experience (see Study Analysis Report, 31 October 1989, Issue T-1 "Scope of Payload Crew Training in the PTC") is made that a 5:1 ratio in program size applies to model fidelity - i.e. a fully functional model is 5 times the size of a black box model. In SCS Issue T-1, it is estimated that payload model complexity spans a 5:1 range in program size for "complex" versus "simple" models. The computational requirements for payload model fidelity levels vary in the same ratio. In general, development and revision time for model software (and PI specifications) will be in proportion to the complexity. Further, the simple models will demand less from other SSF/ground models, resulting in proportionately lower costs across all PTC simulation software.

The update rate is simply a multiplier on the CPU capacity or number of computers required. The proportionately smaller CPU computing requirement may be further reduced by other potentially simpler simulation models needed to support the slow update rate.

The number of payload simulation models is also a multiplier on the CPU capacity or number of computers required. A refinement to this direct ratio may be necessary since additional costs will be entailed if flight equivalent payloads present unique requirements for GSE services, sensor/effector stimulation, Core systems functions/data, and High Rate Link data connections.

The recurring labor cost of developing and testing payload model code can be estimated to equal about ten man-years per model using a programming rate of 150 SLOCs per man month. SLOCs are calculated starting with Appendix A, Section 2.4, "Payload Representation". The 5:1 ratio reduces the average 20,000 SLOCs per model to an estimate of only 4,000 lines. Consequently, software development facility requirements would be estimated at 3 MIPS CPU capacity plus 60 MB disk storage per payload model (assuming a one year payload model development cycle).

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) full func- tionality	0.5 MIPS* on MC per P/L+ 33 development WSs of 8 MIPS** each (+ PI remote interface as needed)	None (unless P/L model requires F/E C&D panel)	Advanced develop. toolset, hi-fi Core & environ. models	20 K SLOC program per P/L*
(b) black box func- tionality	0.1 MIPS* on MC per P/L + 11 development WSs of 8 MIPS**each	None	Basic develop. toolset	4 K SLOC program per P/L*

\* Based on the weighted average simple, medium, and complex, model size from Section 2.4.2 of Appendix A (and run at standard average update rate of 2 Hz)

\*\* Development workstation is per Section 2.21 of Appendix A.

### **3.2.4 Fidelity of Core Systems Models:**

- a) flight equivalent functionality
- b) simplified functionality

#### **Trainers:**

Flight equivalent core models, such as might be obtained from WP02, may not be practical for most payload simulations. The full fidelity they provide is not necessarily translated in training fidelity visible to the trainee.

Simplified functionality core models can, in most cases provide full fidelity training. Realistic core functions can be simulated with smaller models and far less overhead than using flight equivalent software.

#### **System:**

Flight equivalent core models would require payload models to provide a full core system interface. For example, to interface to electrical power, a payload simulation would have to model power-on current levels (Amps, Volts), current drawn fluctuations, power up, power down, and so on. Payload training may only require a model that has power on or off modeled.

Simplified functionality core models would be smaller in size. Examples of functions that require only simple simulation are electrical power, fluid management, and the Process Materials Management System (PMMS). There might be high fidelity required for parts of some functions, C&T for example. But the part of C&T that is specific space to space communication could be omitted without degrading payload training.

Core models are executed in each trainer host. A problem exists when the payload model is designed to support payload training, and interfaces to simplified functionality core models. The SSTF core models are full fidelity, and require many more parameters to be modeled than needed for high fidelity payload training.

#### **Cost:**

Flight equivalent Core system models are expected to be available. Their fidelity and complexity will demand complex interfaces of payload simulation software. Upgrading and maintenance, however, should be significantly easier than with custom core simulation software. Considering the limited scope of Core data needed by simulated or flight equivalent payloads, costs associated with acquiring, integrating, and driving the flight equivalent software would be greater than that for simpler models with selective functionality.

Simplified functionality custom model software is an additional development cost over the use of flight equivalent Core system model software. If the flight

equivalent core models are modular enough, simplified functionality may be achieved by using only the required modules.

The bottom line costs are likely to be less for simplified functionality core models than for the full-up system because of the expensive computers required to host the flight equivalent software and the high fidelity models required to accommodate this software.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) F/E func- tionality	6 MIPS* on MC per trainer	None	49K* SLOC program	None
(b) simpli- fied func- tionality	1 MIP** on RS per trainer	None	16K** SLOC program	None

\* This is for flight equivalency constrained to payload important areas - for 7 core models of 7K SLOCs each. Also see estimate and logic in Section 2.2, "Core Systems Representation", of Appendix A.

\*\* This is based on 33% of the function (and program size) at half the update rate of flight equivalent Option (a)



### 3.2.5 Fidelity of Environment Models:

- a) full dynamic effects
- b) simplified effects

#### Trainers:

Full dynamic effects models would provide the highest fidelity training. However, full dynamic effects models have little training value for the majority of payloads since the effects of environment models are not visible to the trainee. In the few payloads where the effects are visible, full dynamic effects models will be essential.

Simplified effects models will be quite adequate for most payloads.

Environment models are important only to the extent that the science dynamics modeled in the payload models respond to the environmental states. In some cases, full dynamic effects models may be required to drive flight equivalent payloads or their associated payloads stimulators.

#### System:

Full dynamic effects environmental models will be large and complex, which will require both memory and CPU processing time.

Simplified functionality environmental models would be smaller in size, and require less memory and CPU processing power. There might be high fidelity environment models required for parts of some functions, GN&C for example.

Environment models are executed in each trainer host. A problem exists when the payload model only requires simplified environment models but only complex models are available. The payload model may have to be made more complex to interface to a complex environmental model. However, if the environmental models are cleverly designed, only the parts needed could be selected for use, and the payload model could be only as complex as required for training.

#### Cost:

Some environment models may be obtained from WP01. Models providing full dynamic effects will only be needed to drive flight equivalent payloads. In terms of SLOCs, a 3:1 difference in code size is estimated to implement full versus simplified dynamic effects.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) full dynam- ic effects	4.5 MIPS on MC*	None	24 K SLOC* program	None
(b) simpli- fied effects	0.75 MIPS on RS **	None	8 K SLOC** program	None

\* Assumes 50% more functionality than model used for module trainer estimated in Section 2.5, "Environment Representation", of Appendix A.

\*\* Simplified means 50% less functionality than full dynamic model at half the update rate.

### 3.2.6 Use of DMS Kits:

- a) complete in all trainers
- b) complete in module trainers
- c) partial in all trainers
- d) simulated in all trainers

#### Training:

Use of DMS Kits for training will provide the highest fidelity training possible. The confidence that the trainees will have in the training will also be high. The MSFC Payload Crew Training Complex (PCTC) provides excellent, high fidelity SpaceLab payload training. Still, a number of crew trainees have, on their own, made their way over the the MSFC SpaceLab Software Development Facility (SDF) to observe the flight computers, flight payload interfaces, flight support hardware, and flight software in action to gain further confidence in their readiness to accomplish the goals of a flight. The SCS Study Task 6 Technical Demonstration, given in August 1989, showed the potential synergism between a flight equivalent software development and verification facility and flight equivalent system use for training.

Use of DMS Kits will also permit the most realistic non-orbital training with flight equivalent payload hardware and flight payload software. The PDRD - SSP 30000, Sect 4, Part 3, 3.12 Training; in 3.12.I states, "High fidelity training systems shall have the capability to use flight software" and in 3.12.H, "Flight type hardware shall be utilized in ground training applications whenever: The use of such equipment would be more economical to the SSP than building replicas; substitute hardware cannot provide the required fidelity or training results". The trend for Spacelab is toward more use of flight equivalent hardware and software for payload training.

Simulating DMS without the DMS Kit flight equivalent hardware and software would also provide high fidelity training. The best example of this type of training is the many aircraft cockpit flight simulators used to train pilots. The difference between the PTC and these aircraft simulators is that 4 to 12 of the instruments to be trained on in the PTC will be swapped out every few months (in each increment). This is not true in the aircraft flight simulators. This means the use of flight equivalent payload simulations has the potential to be more cost effective. Also, running payload flight software and flight hardware will require, for timing and electronic interfaces, the hardware that is essentially equivalent to an SSF DMS Kit.

#### System:

For the trainers in which complete DMS Kits are used, flight equivalent software will be run with appropriate interfaces to simulation software necessary to achieve a realistic SSF environment. This will demand more complete and higher fidelity Core and environment representations than for a simulated DMS.

Complete and exclusive use of DMS kits in all trainers obviates the need to build any DMS simulations and provide CPU capacity to run these models.

Complete DMS Kits only in module trainers (Option b) means the PTTs will be non-DMS trainers. The DMS Kit will have to be simulated with software and hardware.

The partial DMS implementation (Option c) involves interfacing key DMS components directly (no SIB) with the simulation host or sharing key DMS components across trainers.

The partial DMS implementation presents a unique possibility to achieve high payload fidelity without complete DMS Kits. By employing only the MDMs (per Paragraph 3.2.8, "Use of MDMs") and a high proportion of flight equivalent or comparable payload instruments, an effective partial design is possible. The MDM would be interfaced directly to the Trainer Host's which would simulate all other necessary DMS functions. The same CPU platform, or additional networked platforms, would host payload models when they were employed. Corresponding C&D panels for these simulators could be driven through the MDM. The design would provide a payload simulation system that could plug directly into the SSTF's flight equivalent DMS array (see Paragraph 3.2.23, "Payload Simulator Transportability to SSTF") as well as into the PTC's trainer hosts. Simulation functions obtained from the SIB in complete DMS designs would be handled by the host. The risks associated with partial DMS are much the same as those in Option d.

Simulating DMS (Option d) to replace DMS Kits would require a significant amount of hardware and software. Since the DMS Kit design is still evolving, even the currently estimated amounts of software and hardware may not be enough to insure that flight equivalent payload software and flight equivalent hardware will run, i.e. there is some risk that further hardware and/or software would be needed to get the job done. In addition, the IP Data Systems must also be simulated. Finally, any flight software that could be run on DMS Kits would have to be simulated, e.g. C&T.

#### Cost:

The cost differential between certified flight equivalent DMS components (Option a) and generic COTS hardware of comparable performance is likely to be greater than 5:1. Development of custom software used with COTS hardware to simulate the DMS (Option d), on the other hand, will add programming labor of approximately 206,500 SLOCs, or about 115 man-years, plus any subsequent revisions during the 30 year life cycle owing to an SSF change in design or functionality. The SLOC estimates are based on the expectation that the simulation code size will be about the same size as the flight equivalent DMS software estimates (see note below). The labor estimate reflects a coding rate of 150 SLOC per man month.

The cost of Option b includes both DMS Kits and DMS simulation software for the non-DMS Kit PTTs.

Option c would combine DMS Kit components and COTS hardware and software costs. The cost of integrating, testing, and making the small amount of

software estimated work could be very high based on the SCS Study Task 5 effort. This approach looks attractive, but could also be the most expensive.

Simulating DMS (Option d) means not using ITVE (see paragraph 3.2.22 "Use of SSE/ITVE Tools", since ITVE is designed to operate with DMS Kits.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) complete in all trainers	1 sized DMS Kit* complete (+ SIB) per concurrent trainer	None	F/E Programs including OMA	None
(b) complete in module trainers	1 sized DMS Kit* complete (+ SIB) per concurrent trainer	None	F/E Programs including OMA + DMS Sim S/W for PTTs	None
(c) partial in all trainers	1 partial DMS Kit (- SIB) per concurrent trainer	None	Modified F/E Programs including OMA + 10 K SLOC program	None
(d) simulated in all trainers	1 sized COTS complement** per concurrent trainer	None	81.5 K SLOC*** DMS simulation programs + 125 K SLOC SIB, TGU, MDM, & GSE sim + F/E S/W Sim (C&T)	None

\* A complete DMS kit includes one or more of the following items: SDP, SDDU, RC, HRL, MDMs, MPACs, TGU, MSU, PP, SC, BNIU, BR, and several different interfaces and monitors - see DMS Kits Requirements and Allocations Data Base Update, NASA-MSFC, for detailed listing of different kit configurations.

\*\* Consisting of hardware listed below

- 29 Host  $\mu$  Computers (equivalent to 80386 in speed and power) for SDP simulation
- 27 PS/2-80s + peripherals for MPAC simulation
- 56 Flight Equivalent MDM I/F cards (40% F/E P/Ls assumed)

\*\*\* Simulation of F/E DMS at 100% of functionality and code sizes from DMS Software Requirements Specs (SRS) documents total calculated as follows:

Caution & Warning	.2 K
Network O/S	20.5 K
OMA	25.0 K
O/S ADA Run Time Environment	11.5 K
Standard Services	4.3 K
Data Storage And Retrieval	1.5 K
User Support Environment	5.9 K
System Manager	7.1 K
MODB Manager	5.7 K
Total	<u>81.5 K</u>

These numbers were obtained by translating from the KBytes given in the Software Requirements Specs (SRS) documents using 3.5 Bytes/DEMI and 10 DEMIs per SLOC.

Size of the other functions is estimated, based on required functionality and experience, as follows:

SIB	~50 K
MDM	~50 K
TGU & TD	~5 K
GSE	<u>~20 K</u>
Total	125 K

### **3.2.7 SIB's Interface to Host Computer:**

- a) proprietary channel attach
- b) LAN

#### Training:

The type of host interface would be transparent to the trainee. However, the additional flexibility provided by a LAN potentially provides improved training since it would allow more options in trainer configurations.

#### System:

The proprietary channel attach will preclude the possibility of sharing hosts across DMS trainers; i.e., a particular host will be hardwired to a DMS trainer. This choice significantly restricts reconfiguration options and potentially increases the total number of hosts needed. One host per trainer will be required.

The LAN interface would permit the connection of several hosts to a SIB, enabling each DMS kit to be driven by a different host or shared across hosts. The arrangement would provide considerable flexibility in quickly forming different host configurations to meet training needs. One host per concurrent trainer session would be required. The high rate throughput of the trainer host to the SCS network and the complexity of multiplexing concurrent host sessions to the SIB are potential problems with this approach. Note that the required throughput of 53.6 Mbits per second [ref DMS Kit CEI Spec ] is within FDDI network bounds.

The LAN interface also allows optimum choice of type of CPU platform to be used since a host with the proper interface can be attached to the LAN. A direct SIB/host interface is constrained by the proprietary point-to-point interface.

Note that to capitalize on the potential host reconfigurability, the Session Management Function will need additional functionality to effect and manage cross-trainer interconnections. Further, if a SIB is shared among trainers, additional systems level software is necessary to enable trainer configuration and arbitration control.

#### Cost:

Option (a), "proprietary channel attach" would be substantially more expensive than the "LAN" option. Estimates are that the proprietary channel interface along with the supporting circuitry to other components of the system covered exceed the cost of the LAN option for the PTC/SCS. This option's principal expense comes from the direct attachment of the host to each trainer. On the other hand, this would allow the use of a low cost SCS LAN (Ethernet) for interhost connections, since the high speed transfers would be off the LAN. Because of the distance between host and trainer within the PTC, it is necessary to include fiber optic components in the proprietary SIB/host channel attachment. This further adds to the cost.

Option (b), "LAN" connection can result in significant savings primarily because the number of hosts needed is equal to the number of concurrent training sessions - a result of allowing a given host to connect to any trainer. However, the requirement for high data rate transfers between host and trainer results in a far more expensive LAN (FDDI based or similar).

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) propr. channel attach	Propr. Channel Interface per trainer + Fiber Optic extensions	None	Associated Propr. Channel to SIB Interface Program (ITVE provided)	None
(b) LAN	COTS NIU/BIA per trainer + high speed SCS LAN	None	Associated LAN to SIB Interface Programs	None



### 3.2.8 Use of MDMs:

- a) use MDMs
- b) partially simulate MDMs with software
- c) fully simulate MDMs with software and hardware (capability comparable to SSF DMS Kit MDM capability)

#### Training:

Flight payload software may be designed to run on, and use facilities of, the MDM. Use of MDMs will permit this payload flight software to be used for training. MDMs will also provide the capability to use flight equivalent payloads for training at the PTC. Currently at the Spacelab PCTC, work is being done to increase the available amount of this type of training because experience has shown it is valuable.

As demonstrated by the current PCTC configuration, MDMs can be simulated. However, neither flight equivalent payloads nor payload flight software are supported by the PCTC equivalent MDM simulation.

#### System:

Flight equivalent payload instruments will plug directly into a MDM. Some of the payloads flight software will run on the MDMs.

For payloads simulated with software that runs in the SCS Host, MDMs are easily simulated in software (option b).

To support flight equivalent payloads with simulated MDMs (option c), sufficient COTS I/O hardware & software must be added to handle signals and timing necessary to satisfy flight equivalent payload demands. The same type of CPU and internal communications available within a MDM must be duplicated to be able to execute payload flight software.

#### Cost:

MDMs are expensive (currently \$239K each).

Simulating them in software is simple, but does not support the use of either flight equivalent payloads or payload flight software for training.

The cost differential between flight equivalent DMS MDMs and generic COTS hardware of comparable performance is likely to be greater than 5:1. However, COTS hardware will not have the same interface as a MDM, so to duplicate the MDM interface, custom hardware would probably have to be built. Also, development of custom software, used with COTS or custom hardware to simulate the MDM, could add significant programming labor.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) use DMS MDMs	1 DMS MDM for every F/E P/L in trainer's shipset	F/E P/Ls	F/E MDM programs (+ support for PI's user code)	F/E P/L S/W and Install appropriate DMS Kit S/W updates
(b) partially simulate	0.2 MIPS per trainer on MC	None	2 K SLOC MDM simulation	Update MDM simulation when MDM design or functionality changes
(c) Fully simulate	1 COTS or custom MDM processor + memory + custom I/O board per every F/E P/L	F/E P/Ls	50 K SLOC MDM simulation and I/O processing S/W	F/E P/L S/W and Update MDM simulation when MDM design or functionality changes

### 3.2.9 Use of OMGA

- a) flight equivalent
- b) simulate

#### Training:

A flight equivalent OMGA would provide a more realistic simulation of ground operation activities over a custom simulation. Paragraph 3.2.6, "Use of DMS Kits" and Paragraph 3.2.4, "Fidelity of Core Systems Models" discuss issues related to OMGA use.

#### System:

Additional hardware would be needed since using flight equivalent OMGA requires an equivalent to the operational ground based computer to host this software. The POIC should provide this.

Development of unique OMGA simulations will entail a significant, one-time, development effort requiring adequate development and testing system capacity.

Whether OMGA is flight equivalent or simulated, it will be necessary to drive this function in order to produce ground control exchanges. This necessity can be met with either an instructor or trainee performing the role of the ground personnel, or an "auto-controller" model which realistically simulates the behavior of ground operations personnel.

#### Cost:

Software estimates for the OMGA are not yet available, but we estimate that the OMGA will be at least 50K (twice the size of the OMA).

An OMGA simulation, not including MPS, is estimated to be 50% of that sized for the operational OMGA, or 25K. The "50%" is based on the hypothesis that the simulated function will need no more than 50% of the functionality of the flight article.

#### Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) F/E	6 MIPS on MC per trainer	None	50K SLOC F/E OMGA*	None
(b) simul- ated	2 MIPS on RS ** per trainer	None	25K SLOC program**	None

\*\* Based on size for simulated ground control function from Section 2.8, "POIC - DMS Interface", in Appendix A.

### 3.2.10 Concurrent Independent Training Sessions

- a) 2 US Lab Modules, 0 US Lab PTTs, 3 LoFi Sims, 1 ESA or 1 JEM PTT
- b) 2 US Lab Modules, 3 US Lab PTTs, 1 ESA or JEM PTT
- c) 2 US Lab Modules, 3 US Lab PTTs, 1 ESA, 1 JEM PTT

#### Training:

Independent training sessions are defined as training one or more trainees on a specific timeline or On-board Short Term Plan (OSTP) for one or more payloads.

Extensive analysis by TRW, NASA training, and Boeing shows that 5 independent training sessions (or scenarios) are required to support SSF operation. These involve concurrently operating trainers as shown in option (c) since NASA training personnel have as a requirement a limited consolidated increment training where one or both of the IP PTTs work in concert with the US Lab Module Trainer.

Option (b) represents the current CBR baseline which provides 6 independent scenarios for training, but no consolidated increment training.

Option (a) represents a approach where early training is procedural at the PTC using LoFi simulations with all the high fidelity science training being done at PI sites.

#### System:

The number of concurrent trainer sessions has a significant effect on the system resources. The number of host computers and DMS Kits is obviously affected. Also, system level resources must be sized in direct proportion to the number of concurrent sessions. These resources include the multiplex speed of the real-time portion of the Session Management Function, bandwidth for the real-time portion of the PTC/SCS LAN, the number of instructor stations, and the storage speed/capacity supporting session recording for analysis and freeze capabilities. Initialization download capacities for a given reconfiguration turnaround will also be affected. For trainer types configured with shared simulation resources, the number and capacity of shared services such as audio-video and GSE/stimulation will be proportional to the number of concurrent sessions on these trainers.

The number of concurrently active payloads per trainer may also affect the complexity and processing power necessary at each instructor station in order to monitor training situations involving several active payloads.

#### Cost:

The major cost factor is the total number of hosts, DMS Kits, and trainer components. It should be noted that two module trainers are not equivalent to four part-task trainers, and each type will require more of some resources than does the other. Further, as more trainers are put in operation simultaneously, more copies of the individual flight equivalent payload instruments will be needed.

Other cost increases are limited to the PTC/SCS Network scaling to handle the proportional increase in instructor station traffic with additional independent training sessions.

Comparison:

See paragraph 3.2.6 for DMS Kit sizes and details.

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) 2 US Lab Modules, 0 US Lab PTTs, 3 LoFi Sims, 1 ESA or 1 JEM PTT	2 sized Hosts & 2 sized DMS Kits for US Lab Modules + 3 WG for LoFi + 1 Host & 1 ESA & 1 JEM DMS Equiv. Kit for IP PTTs	None	ITVE + DMS S/W + IP DMS Equiv. S/W+ Prototyping S/W	LoFi Sim S/W or data files for LoFi P/L sims
(b) 2 US Lab Modules, 3 US Lab PTTs, 1 ESA or JEM PTT	2 sized Hosts & 2 sized DMS Kits for US Lab Modules+3 Hosts for US Lab PTT + 1 Host & 1 ESA & 1 JEM DMS Equiv. Kit for IP PTTs	None	ITVE + DMS S/W + IP DMS Equiv. S/W + DMS Simulation S/W for non-DMS PTTs	Updates to the DMS Simulation as DMS evolves
(c) 2 US Lab Modules, 3 US Lab PTTs, 1 ESA, 1 JEM PTT	2 sized Hosts & 2 sized DMS Kits for US Lab Modules+3 sized Hosts & 3 sized DMS Kits for US Lab PTTs + 2 Hosts & 1 ESA & 1 JEM DMS Equiv. Kit for IP PTTs	None	ITVE + DMS S/W + IP DMS Equiv. S/W	None

### 3.2.11 Per Cent of Flight Equivalent Payload Simulations:

- a) 40% flight equivalent payloads
- b) 10% flight equivalent payloads
- c) 0% flight equivalent payloads

#### Training:

Providing trainers that support flight equivalent payloads will ensure the high fidelity payload training required to accomplish the SSF mission

Realistic aircraft flight simulators are built with no flight equivalent hardware. However, these aircraft simulators do not have 4 to 12 of their instruments changing every 90 days, as will the PTC trainers. This means the use of flight equivalent payload simulations has the potential to be more cost effective. Even the SSTF, which is more analogous to the aircraft simulator than the PTC, has adopted DMS Kits to supply the proper fidelity of SSF training.

#### System:

Flight equivalent payloads can be supported by utilizing DMS kits with MDMs. The quantity of requisite flight equivalent DMS Kit components (hardware & software) and SIBs is proportional to the number of supported flight equivalent payloads. Conversely, some percent of the time software-only simulation models will be used in the same racks, which means that the SCS must encompass the full capability to develop and drive each trainer with software models, as well as accommodate flight equivalent hardware.

#### Cost:

Supporting flight equivalent payloads is most economical with DMS Kits (see 3.2.6 "Use of DMS Kits").

The trainer host MIPS capacity to execute payload simulation models is a multiple of the number of simulated payloads. There are also commensurate sizing impacts on the network and simulation executive, among other functions, within a trainer.

More software simulated payloads means more model and associated software development as well as more testing. To the extent that useable models are not available from the PIs and would have to be developed onsite, there is a proportional increase in the number of developer and testing stations and servers. However, the IT&V size will remain essentially constant, since the number of payloads to be integrated is the same whether they are flight equivalent or software implementations.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) 40% F/E	60% of WSs & hosts in development facility in option (c)** + one sized DMS kit per concurrently operating trainer + 1 MDM for each rack supporting F/E P/Ls*	F/E instruments & panels for 40% of all P/Ls	Model & panel** develop toolsets	F/E P/L programs from Pls + items below for (c) per 60% of P/Ls**
(b) 10% F/E	90% of WSs & hosts in development facility in option (c)** + one sized DMS kit per concurrently operating trainer + 1 MDM for each rack supporting F/E P/Ls*	As above for (a)	As above for (a)	F/E P/L programs from Pls + items below for (c) per 90% of P/Ls**
(c) 0% F/E (100% sim)	34 develop WSs of 8 MIPS*** + Development Host Computers (1 for every 15 developers)** + LAN & server for each computer	None (other than P/L panel specs from Pls)	As above for (a)	Develop Sim S/W including test & integration for each P/L**

## \* Sized DMS list:

- 1 Large DMS Kit per U.S. Lab Module Trainer
- 1 Large DMS Kit & 1 ESA & 1 JEM DMS Kit equivalent for the IT&V facility
- 1 Small DMS Kit per 4 PTT Racks
- 1 Small DMS Kit for development unit test
- 1 SIB per Kit
- 1 IP DMS Kit equivalent for each set of IP PTTs or each IP Module trainer

\*\* Impact only if PTC supports P/L model development (see 3.2.15 "P/L Models Developed on PTC/SCS")

\*\*\* Workstation quantities are for model development per Section 2.21 of Appendix A.

**3.2.12 Trainees and Payloads per Quarter:**

- a) 90 day crew & 90 day payload increments
- b) 45 day crew & 90 day payload increments
- c) 45 day crew & 45 day payload increments

**Training:**

The options under this issue are a major factor in determining the number of concurrent training sessions that have to be sustained in order to complete the required number of hours of simulation training on each payload.

**System:**

Enough Module trainers and PTT racks with associated computers must be available to support the required training hours. The baseline of 2 US Lab module trainers, 9 US Lab PTT racks, 5 JEM PTT racks, and 11 ESA PTT racks will accommodate option (a), given enough computer resources to support increased concurrent training sessions. Scenarios of, "90d crew & 90d p/l intervals", "45d crew & 90d p/l intervals", "45d crew & 45d p/l intervals" were examined (See section 1.2.1 for results and Appendix C for the analysis details).

Additional system capacity for storing session scenarios, downloading configuration and initializing data, capturing and analyzing session performance, and maintaining training records is a multiple of the number of trainers used for training.

**Cost:**

The cost comparisons were made with the 10% change out rate shown in the comparison table as this is the number currently in use by NASA training. The amount of training required doubles when the number of trainees doubles, or the number of payloads doubles. Doubling either requires twice as much simulator hands on training time. Further detailed analysis by Boeing training personnel has confirmed the analysis shown in option (b). See also 3.2.10, "Concurrent Independent Training Sessions" and 3.2.13 "Payload Changeout per Increment".

**Comparison:**

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) 90d & 90d	Baseline number of trainers	10% new F/E P/Ls per quarter	Complement of F/E sim programs per quarter	10% new F/E or model programs per quarter
(b) 45d & 90d	Twice the number of trainers	10% new F/E P/Ls per quarter	More complex Session Mgmt Func: 0.5K SLOC	10% new F/E or model programs per quarter
(c) 45d & 45d	Four times the number of trainers	20% new F/E P/Ls per quarter + C&D panels	More complex Session Mgmt Func: 10 K SLOC	20% new F/E or model programs per quarter



**3.2.13 Payload Changeout per Increment:**

- a) 15%
- b) 12%
- c) 10%
- d) 5%

**Training:**

No effect on training except potential loss of training time while system is being reconfigured.

**System:**

The load on the IT&V will increase in proportion to the percent change-out. The load on the development function will increase in proportion to the percent change-out.

The change-out rate and number of increments overlapping in the PTC will determine the number of co-residing payloads and, thus, the aggregate system capacity required for maintaining session scenario and configuration files for a particular combination of payloads.

The reconfiguration time, as a first approximation, would be in proportion to the percent change-out. On the other hand, change-out time can be reduced by appropriate design of the total system, as discussed below in "Costs:".

If we hypothesize that three consecutive SSF increments overlap in the PTC at any one time (as shown in the training loading analysis, section 1.2.1), the accumulated payload changeout is expected to be 15% to 45% of the total PTC complement of payload instruments and models. Thus, reconfiguration time is limited to that needed for changing over this number of payloads.

While software downloads should be relatively efficient, C&D panel and flight equivalent instrument hookups to MDM and GSE may take some time. Note the impact of virtual C&D panels as discussed in Paragraph 3.2.1, "Type of C&D Panel Crew Interface".

New payload simulator development and testing is assumed to be concurrent with preceding increment training.

The completeness (size) of reconfiguration files and the speed of downloading required by different alternatives may affect the central storage and communications capabilities of the PTC/SCS.

**Cost:**

The percent change-out affects the cost in a direct manner. The higher change-out rates will require more people resulting in higher operational costs. As mentioned under "System:", the impact on IT&V and the development facility is in proportion to the percent change-out, and so the associated cost.

Reconfiguration time may be reduced from the adoption of design options such as the LAN option for SIB connection in Paragraph 3.2.8, "SIB's Interface to Host Computer", or the interchangeable platform option in Paragraph 3.2.24, "Simulator Transportability between Module and Part-Task Trainers". The higher costs of rapid reconfiguration capabilities are traded off against the loss of use of facility operations during periods of reconfiguration and the associated idle manpower of the training staff.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) 15%	Baseline Development *** & IT&V Facilities upscaled 67%	Approx 13 new SSF P/Ls*	Basic development *** and test software environment required	PI F/E programs or 13 X 20K SLOC programs**
(b) 12%	Baseline Development *** & IT&V Facilities upscaled 33%	Approx 10 new SSF P/Ls*	Basic development *** and test software environment required	PI F/E programs or 10 X 20K SLOC programs**
(c) 10%	Baseline Development *** & IT&V Facilities upscaled 20%	Approx 9 new SSF P/Ls*	Basic development *** and test software environment required	PI F/E programs or 9 X 20K SLOC programs**
(d) 5%	Baseline Development *** & IT&V Facilities	Approx 4 new SSF P/Ls*	Basic development *** and test software environment required	PI F/E programs or 4 X 20K SLOC programs**

\* Based on a one week reconfiguration time. If reconfiguration is to be done in 8 hours, then add 60MB virtual memory. (To buffer downloads of increment configuration data sets, simulation models, and session scenarios) + quick connect racks + LAN switching.

\*\* Based on estimate of average payload model size from Spacelab experience. See SCS Study Report, Issue T1 in Volume 5, and Section 2.4, "Payload Representation", of Appendix A.

\*\*\* Impact only if the PTC/SCS supports P/L development.

**3.2.14 Representation of DIF:**

- a) dynamic simulation
- b) table driven simulation
- c) none

**Training:**

Dynamic simulation would provide a high degree of realism of the DIF representation. A table driven, or "static" simulation would be of lower fidelity but for PTC payload training purposes, would probably be adequate.

**System:**

The DIF simulation under consideration here, whether dynamic or static, is only intended to provide the status type information normally provided by the DIF to the POIC. Either should be a relatively insignificant increase in system loading including some communications increase.

**Cost:**

Estimates of code size for simulating necessary DIF functions are based on OMGA estimates and C&T size estimates. The C&T bandwidth being passed on to the DIF will determine the additional CPU capacity for processing a dynamic stream. This processing is not included in the comparison below but would involve both additional hardware, firmware, and software.

**Comparison:**

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) dynamic	2.2 MIPS on MC or RS per trainer*	None	45K SLOC program*	None
(b) static	0.2 MIPS** on PC per trainer	None	4.5K SLOC program**	None
(c) none	None	None	None	None

- \* Uses combination of OMGA (as sized in Paragraph 3.2.9, "Use of OMGA") and C&T (as sized in SCS DMS SRS). See the discussion on software sizes from the DMS PDRs in Paragraph 3.2.6, "Use of DMS Kits".) for total of 45K SLOC, all run at 4 Hz update rate.

- \*\* Estimated at one tenth of dynamic values.

### 3.2.15 Software Payload Models Developed on PTC/SCS:

- a) 50%
- b) 25%
- c) 0%

#### Training:

This issue will have no effect unless trainers are borrowed for use for development unit test or as an IT&V facility while development is conducted independently for model check outs and debug.

#### System:

The percentage of payload models to be developed will determine the development and test capacity requirements required from the system. The number of workstations and the host capacities will be directly proportional to the percentage of payloads developed on PTC/SCS. In addition, the Development Facility LAN will have to be sized to handle increased development related traffic. Payload changeout rate affects this (see 3.2.13 " Payload Changeout per Increment).

#### Cost:

The baseline Development Facility and IT&V Facility requirements consist of, by the current design, three development hosts, one IT&V host, and 32 workstations. The determination of these requirements is discussed further in the "Local Host Design" section of Volume 3 of the PTC/SCS study. Capacity and costs are approximately proportional to the number of models to be developed (in the course of a year). Also, recurrent communication facility costs for remote access for any of this development must be added. changeout rate used was 5%.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) 50%	33 develop WSs of 8 MIPS* (+PI remote interface as needed) + base IT&V in (c) + 3 devel. hosts	None (other than P/L specs from PIs)	Model & panel develop toolsets	20K SLOC *** models + 2 man week virtual panel develop. per P/L
(b) 25%	50% capacity of option (a)(+PI remote interface as needed) + 2 devel. hosts	Same as (a)	Same as (a)	20K SLOC *** model + 2 man week virtual panel develop. per P/L
(c) 0%	6 IT&V WSs of 11 MIPS**	None	None	Program test & integration per P/L

\* Workstations for model development are per Section 2.21 of Appendix A with the quantity capable of supporting one payload in 90 days; add one WS for developing virtual C&D panels

\*\* IT&V stations are represented as developer workstations with additional MIPS per Section 2.24, "Integrate and Test Simulations", of Appendix A

\*\*\* This limitation is based on the assumptions on number of programmers developing software (33) and the productivity rate given in Paragraph 3.2.3, "Fidelity of Payload Models"

**3.2.16 PTC/SCS Remote Developer Capability:**

- a) use for all simulated payloads
- b) use for 50% of simulated payloads
- c) none

**Training:**

No effect.

**System:**

Providing a remote developer capability is implemented by the provision of high speed dial-up ports in the development facility. The capability also requires local support for hardware reconfiguration. Additional software support for security and configuration management will likely be necessary.

**Cost:**

The basic cost is the addition of one communications port/modem (assumed 9600 baud performance) to the SCS System Management Host for each external payload model. Of course, a continuing operational cost will be the phone line charges necessary to support remote developers. Also, overhead costs of SCS communications and executive functions will increase the host capacity requirement by about 0.2 MIPS per external model.

A secondary cost results from the security problems inherent with remote phone access. This concern must be met with adequate security safeguards - at greater system cost - to insure that no unauthorized system use is possible due to remote access.

In compensation, as the amount of remote access is increased, accommodations for local access can be reduced.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) all	36 dial-up ports* and modems + 7.2 MIPS (+ SCS develop resources)	None	None (other than Security & Management)	None
(b) 50%	18 dial-up ports* and modems + 7.2 MIPS (+ SCS develop resources)	None	None (other than Security & Management)	None
(c)	None	None	None	None

- \* Based on SLOC productivity estimates (150 SLOC per man month), estimated size of payload models (20K SLOC) and number of new payloads per 90 day period (6-9). To size a reasonable worst case, 90% S/W models are assumed here. The quantities would be halved if approx. 50% F/E payloads were used (per discussion in Paragraph 3.2.3, "Fidelity of Payload Models".)

### 3.2.17 Consolidated Increment Training:

- a) provide dedicated trainer
- b) provide for linkage of US Lab module trainers with IP PTTs
- c) none

Consolidated Increment Training is, in the PTC context, payload training for payloads (a realistic shipset of all that could be running simultaneously given power and other resource constraints) in all three Labs (US, ESA, and JEM).

#### Training:

Providing this training utilizing a dedicated trainer (a) would provide Consolidated Increment training and a readily available Operations Evaluation capability to simulate and solve inflight payload problems. However, the amount of this type of training required is small (less than 32 hours per increment based on Spacelab experience.)

Option (b) would provide limited Consolidated Increment training since the IP PTTs hold only US sponsored payloads, and the IP PTTs will not be positionally correct.

#### System:

Option (a) would require a separate trainer consisting of three modules (US, ESA, & JEM) and associated DMS Kit and Data System Kits for the IP modules and a host computer.

Option (b) can be implemented by utilizing the existing US Lab module trainers with a real time LAN between the host computers and some added software to coordinate.

An alternate way of implementing Option (b) would be to have a second connection from each IP PTT to a larger host computer that could drive all three trainers. This would eliminate the required real-time LAN. Some additional coordination software would still be required.

There would be some additional software in the Session Management Function for Option (b) to provide selective session control over multiple trainers.

#### Cost:

The cost of Option (a) is essentially the cost of three module trainers, three DMS Kits or Data System Kits (including a SIB and two SIB equivalents), a large host computer, plus the cost of adding two gateways to interconnect the trainers.

Option (b) can be implemented simply by providing two sets of gateways/bridges: one set interconnecting the Trainer LANs; and one set interconnecting the Trainer Hosts, and some additional control software.



Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) dedicated trainer	3 module trainers + 3 DMS strings + 2 bridges + SM of 47.5 MIPS* + 1 SIB + 2 SIB equivalents + 1 A-V unit + 4 WS of 16 MIPS**	Replicates of F/E P/Ls for simultaneous module & consolidated training	Approx 2K SLOC for reconfig. function in the Session Management Function	None
(b) limited	4 bridges + a real-time LAN + 1 A-V unit	None	Approx 2K SLOC for reconfig. function in the Session Management Function + COTS S/W for LAN & bridge communications	None
(c) none	None	None	None	None

\* Consolidated trainer host estimate for SCS Local Host design per Refined Conceptual Design Report, SCS Study Report Vol. 3, Section.3.3.3.

\*\* Workstation sizing for Instructor Station per Section 2.11, "Instructor Control and Monitoring", of Appendix A.

### 3.2.18 POIC Interface:

- a) full bandwidth (100 to 300 Mbps)
- b) limited bandwidth (10 Mbps)

#### Training:

Considerations here concern the realism of the POIC interface. Use of the full bandwidth (100 to 300 Mbps) is necessary to support a High Rate Link, which in turn is necessary to support graphics data transfer. However, from a training point of view, the system only has to appear to be transferring this data. Therefore the full bandwidth is not required for crew or POIC training purposes, but may be required by PIs for high rate data. Closely related is the function of dynamic data generation vs. static data generation. Dynamic generation could provide a much more realistic simulation to the trainee than static. However the effect on quality of training is marginal.

#### System:

The interface for command/status and audio traffic, while substantial, is straightforward. The high rate link data generation, however, must be supported dynamically within the PTC in order for this data to be scientifically meaningful. If the full bandwidth option (100 to 300 Mbps) is chosen, data would pass through the C&T processor/controller. At the present time, bandwidth beyond 100 Mbps must be supported by implementing multiple channels. However, by AC it is reasonable to assume that single fiber links of 300 Mbps will be available.

High rate science data goes directly from the payload to the user via the PTC High Rate Link (HRL) system. The rate at which dynamic or static data has to be generated will determine the complexity of each implementation option.

It makes sense to assume as a reasonable worst case that the full bandwidth channel requirement is limited to one trainer session concurrently, and thus the facility would be shared among trainers.

The effect on complexity and cost is an interaction between the bandwidth alternatives and the source alternatives (dynamic, table driven, etc.).

The POIC interface is implemented using the SCS System Manager Host to control the routing and synchronization of the data interchange. In implementing this link, the 100 to 300 Mbps option involves an order of magnitude more complexity and cost than the 10 Mbps option.

To generate the data, pre-programmed streams might be supported centrally for all trainers. Whether centralized or distributed, large and fast mass storage will be required, limited by the assumption that only one such stream is passed on to the POIC at one time.

Cost:

The hardware requirements consist of a network adapter and router that can be controlled by the SCS System Manager Host or a separate host and provide the prescribed throughput, plus the network interface unit and the physical network media connecting to the POIC line. Currently, the cost differential for a FDDI implementation of the full bandwidth option versus an Ethernet implementation of the limited bandwidth option (10 Mbps) is at least 10:1. This differential may decline to around 5:1 in time for an SSF AC version of the PTC/SCS.

The cost to generate full bandwidth dynamic data streams consists of: 1) the payload source generation, and 2) the subsequent C&T processing. The former, although interactive, could reflect bandwidth stemming primarily from large blocks of cohesive data (e.g., buffered image frames) that would not react on the fly to concurrent simulation events. Temporal dynamics would only take effect at the juncture between such blocks. Consequently, the cost of source generation is considered not to exceed a 2 MIPS payload model allocation.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) full band- width	2 FDDI NIU/BIAs + resize the Session Management host by 1 MIPS* (+ C&T Processor of 10 MIPS**) + an additional 2 MIPS per P/L model w/HRL + C&T processor + A-V processor + GSE + P/L stim.	None	8K SLOC for interface function in the Session Management Function* + (Hi-fi environ. model)**	When not F/E, may need P/L models with dynamic HRL capability
(b) limited band- width	1 Ethernet NIU/BIAs + resize the Session Management host by 1 MIPS*	None	If dynamic, add (Hi-fi environ. model)**	None

\* Estimate for process and control of the POIC interface is per Section 2.8, "POIC-DMS Interface", of Appendix A.

\*\* Dedicated C&T processor to enable POIC link is estimated in Section 2.9, "PTC-POIC Link", and Section 2.3.2, "Processing Requirement" of Appendix A.

**3.2.19 Training Sessions with UOF/ROC/DOCs:**

- a) interactive in real time (via the POIC)
- b) interactive in real time (simulate the POIC)
- c) none

**Training:**

Without this function, realistic training between the PTC and the UOF/ROC/DOCs will have to be accomplished by some other means.

**System:**

For this linkage to be meaningful, a real time full duplex interchange of dynamic data must be achieved.

If the actual POIC is not tied into this loop (per Paragraph 3.2.18, "POIC Interface"), then the POIC function will have to be simulated via PTC operations personnel, PTC consoles, and software.

**Cost:**

Costs include a C&T Processor/Controller and associated hardware/software. See also paragraph 3.2.18, "POIC Interface".

**Comparison:**

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) dynam- ic interac- tion via POIC	C&T Proc/Cont + C&T DMS kit with C&T SDP	None	C&T Proc/Cont S/W + C&T DMS kit S/W	Implement HRL dynamic generation
(b) dynam- ic interac- tion, POIC simula- ted	C&T Proc/Cont + C&T DMS kit with C&T SDP plus POIC Console/Work Station	None	C&T Proc/Cont S/W + C&T DMS kit S/W plus POIC Sim. S/W	Implement HRL dynamic generation
(c) none	None	None	None	None

**3.2.20 Use of MODB/RODB:**

- a) all simulation models
- b) limited to Core and DMS models
- c) not used

**Training:**

Use of real MODB/RODB software and constructs will give trainees more confidence in the PTC provided payload training.

**System:**

Adoption of the SSF software protocol and dictionary library impacts all simulation model and data interchange constructions. While this formalism may force the models to have broader scopes and format overheads, the potential for improved code reusability and ease of modification more than outweigh the disadvantages.

While the SSF Program requires that PIs use the MODB/RODB in their payload and payload model software, Option (c) is included for comparison.

The most important aspect of the use of MODB/RODB is that it would provide a higher DMS compatibility and SSTF compatibility in the developed software.

**Cost:**

Note that software is already available from WP02 and prototype RODB software has been run as part of the SCS study. Since this has been done, MODB/RODB should be used in any DMS Kit implementation of SCS.

**Comparison:**

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) all models	Greater on-line storage required	None	Development toolset for PIs & PTC staff supports MODB/RODB	Sourced P/L models conform to MODB/RODB
(b) Core & DMS	Slightly greater on-line storage required	None	Development toolset for PTC staff supports MODB/RODB	None
(c) none	None	None	None	None

**3.2.21 Use of Ada:**

- a) all software
- b) simulation models only
- c) none

Training:

No effect.

System:

Real time Ada works and is being used in numerous DOD systems. Case tools for the development of real time Ada are available. The efficiency of their code products will be adequate for PTC applications. The availability and suitability of Ada for some of the SCS systems software is not likely because of industry trends (toward C) and the need to implement low level functions (some in assembly language).

It is not known whether it will prove practical to impose Ada on payload models developed by the PIs. Payload models in different languages would be hard to link together.

Cost:

If Ada is mandated for all SCS, suitable COTS software (in other languages) may be eliminated, requiring more expensive custom software. When custom software is required the initial low programmer productivity may increase development costs. Ultimately, the improved code reusability gained with Ada should reduce long term system growth costs. Code compatibility with SSF will be important to facilitate transportability. Payload models in different languages would increase operations costs (CM).

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) all S/W	An Ada development facility	None	All custom system & trainer programs	P/L models are PI or PTC provided in Ada @ TBD ratio
(b) sim models only	An Ada development facility	None	All SSF and ground simulation models	P/L models from sources in different languages
(c) none	Non-Ada development facility	None	If non-DMS, potential 30% COTS O/S, Sim Exec, etc.	P/L models from sources in different languages

### 3.2.22 Use of SSE/ITVE Tools:

- a) all software
- b) simulation models only
- c) none

#### Training:

No effect on training.

#### System:

The use of SSE /ITVE tools in the PTC development facility (Options a or b), and compatibility with SSFP software standards affords technical and economic advantages. If other NASA centers follow these SSF standards, the PTC software should transport fairly easily to other training facilities like the SSTF. The SSE/ITVE package, however, may not represent the best tools for each specific job, in our case developing simulation models and code. ITVE will provide data base software (MODB,RODB), interfaces to DMS Kits, and simulation control software that are essential.

No use of SSE/ITVE (Option c) means a different suite of tools must be assembled and built which may or may not be compatible with other SSF centers.

This issue will have no negative effect on the system unless the suite of tools restricts the real time efficiency of the code products, or the extent of the code's control of I/O, interrupts, and memory.

#### Cost:

The incorporation of these development and testing tools in the PTC development facility will be inexpensive compared to purchasing and building a comparable suite of tools. Their implementation may not be the most efficient in a specific situation for producing code. However, replacing SSE/ITVE tools with others will cost significantly more. Also, replacing the ITVE data base software (MODB,RODB), interfaces to DMS Kits, and simulation control software would be very expensive.

Since under the present plan, WPO2 does not plan to respond to any specific requirements from the PTC, but will allow the PTC to use the ITVE products "as is" to make use of the ITVE products, the PTC/SCS design must be engineered to accommodate them. Note that ITVE simulation executive is expected to provide only simulation modes as discussed in Paragraph 3.2.33, "Simulator Modes".

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) all S/W	restricted vendor platforms	None	Restricted languages & development methods likely for all custom software	None
(b) sim models	restricted vendor platforms	None	as above for simulation model development only	None
(c) none	Marginal additional development systems or increased development time	None	Increased cost (as much as 100%) on tools & updates to tools + development of ITVE DB, I/F, & sim control S/W	None



### **3.2.23 Payload Simulator Transportability to SSTF:**

- a) via provision of turnkey system - SSTF to use SCS design & host
- b) via conversion
- c) via adoption of SSTF design

The options defined above as well as the secondary issue of whether to use SSTF hosts are discussed below.

#### **Training:**

Fidelity of payload proficiency training at the SSTF will have a big effect on crew training.

#### **System:**

A turnkey system would provide the payload, DMS, and host portions of the simulators that would interface directly to the SSTF's Core, environment, and session control systems. Option (a) assumes the platform to be the SCS host with DMS, payload software, and I/O subsystems for flight equivalent instruments and C&D panels. The turnkey system would include appropriate extensions to interface with the SSTF Core systems and session management control. Minimum cost, overall, can be expected to come with the PTC/SCS host because its selection criteria are founded strictly on efficient payload simulation.

The conversion approach of Option (b) would convert the payload and DMS software and computer/hardware interfaces to accommodate the SSTF, rather than implement a design that provides a plug compatible standalone payload simulator system or a design that provides a dependent SSTF subsystem. Option (b) assumes that the SSTF uses its own payload host and DMS components. The PTC/SCS must then be designed from the outset to include the appropriate hooks in PTC/SCS payload software and scars in I/O components. To tie the provided system directly into the SSTF and its executive control would then only require conversion.

The conversion option is intended to provide the same systems to the SSTF, but without constraining the initial PTC/SCS design with built-in SSTF compatibility. Instead, the SCS payload software and subsystems are converted after the fact to run in the SSTF environment. It is assumed that the most practical implementation of this alternative would involve the development of conversion utilities to automate the PTC-to-SSTF software translation. Similarly, intermediate conversion equipment would be provided to achieve the proper I/O compatibility.

Option (c) means that the PTC/SCS replicates the SSTF design for payload simulation and enforces this as the PTC design. The design, which uses four sets of DMS Kits with full strings of SDPs, SIBs, and the SSTF hosts, is based on flight equivalent software.

In contrast to other alternatives, Option (c) determines the trainer interfaces that all PTC/SCS systems must support. Option (b), on the other hand, imposes the additional systems support and user labor for the SSTF conversion process.

Cost:

The turnkey approach in Option (a) presents the least impact on the PTC/SCS design and a negligible increment in the PTC/SCS cost. The cost to the SSTF for the turnkey system in this option is essentially the sum of the costs of the individual lab trainers required by SSTF less the host CPU capacities reserved for Core and environment model execution. The host downsizing amounts to a 35 percent reduction in MIPS (per Section 3.3.3 of Volume 3, "SCS Study Report").

Option (b) relies on the development of efficient gateways and software utilities to convert between SSTF and SCS protocols and logical structures. A gateway would be required for each trainer between its Payload Trainer LAN and the SSTF Real Time Simulation Network, as well as a gateway between the central host (SCS) LAN and the SSTF General Purpose Network. Logical conversion of object structure and relations could occur at two levels: one operating at run time as a preprocessor; and the other as a translation utility used to convert PTC/SCS software modules into SSTF software modules during redevelopment. Additional protocol conversion is assumed to occur in the gateways.

Conforming to the SSTF design in Option (c) means adopting the full DMS implementation and support of flight equivalent software, restricting models to the MODB/RODB dictionary, and providing additional hooks and scars where necessary to interface with SSF simulation and system executive control. This presumably would require compatibility with Ada in a Unix runtime environment.

The bottom line is the difference in acquisition and maintenance costs for the SSTF hosts versus the chosen PTC/SCS hosts. While the PTC/SCS hosts can be sized exactly to meet payload simulation software and communications loads, the size of the SSTF hosts would be predetermined and could necessitate using multiple units or sacrificing simulation performance. For the expected high unit price of the SSTF host, much more cost efficient distributed processing host solutions could be implemented in the PTC/SCS.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) provide turnkey system	Any vendor* host and F/E or non-DMS components per trainer + Host I/Fs for SSTF RT Sim & GP Networks	P/L instruments when F/E or C&D panels are used	F/E and/or simulation S/W + PTC/SCS system programs + sim programs	F/E P/L S/W, and/or P/L models and virtual C&D panel development
(b) convert	Any vendor* host and F/E components or non-DMS components including gateways per trainer	P/L instruments when F/E or C&D panels are used	As above plus approx. 10K SLOC conversion S/W	Same as above
(c) adopt SSTF design	SSTF host with proprietary I/O (+ DMS Kits + SIBs) per trainer	F/E P/L instruments	SSTF F/E and simulation S/W	F/E P/L S/W, P/L models and simulation S/W

\* Any vendor means that the choice of trainer host is not required to be same as used at SSTF.

### **3.2.24 Simulator Transportability between Module and Part-Task Trainers:**

- a) interchangeable DMS hardware-software platforms
- b) compatible hooks & scars, via conversion
- c) interchangeable non-DMS
- d) none

#### Training:

Greater interchangeability would mean easier configuration and training scheduling.

#### System:

In Option (a), compatible host systems including hardware, software and DMS Kits are used. While the host systems share the same operating system and input/output drivers (in order to support the same simulation software), trainer hosts could vary in their level of CPU capacity, coprocessor support, and input/output capacity. Both types of trainer platforms would run of the same simulation software code.

The approach of Option (b) would allow the Module and Part-Task Trainers to have independent designs and different hosts, based on the requirement that the PTC/SCS be designed from the outset to include the appropriate hooks in PTC/SCS payload software and scars in I/O components to allow transportability between the modules and part-task trainers. Then conversion utilities would be developed to automate the part-task to module software translation. Similarly, intermediate conversion would be provided to achieve the proper I/O compatibility. The US Lab module trainers are assumed to have the DMS Kits. Thus, no flight equivalent payloads or flight software could be accommodated in the PTTs.

Option (c) is the non-DMS Kit or DMS equivalent option. All trainers would have compatible hosts, including software and hardware.

Option (d) would allow optimum matching of simulation tasks to the hardware and software.

#### Cost:

Option (a) means that if any lab trainers require a full flight equivalent DMS representation, for example, then all trainers would have a flight equivalent DMS implementation and the associated capabilities and costs. However, a COTS interface to C&D panels can be supported in the same PTC payload rack that contains DMS interface hardware.

Option (b) would permit flight equivalent DMS and software simulation to co-reside in the PTC. The difficult part is designing the proper hooks and scars to make

conversion work. Software utilities would have to be developed to convert between module and part-task protocols and logical structures used in the simulation software. Translation utilities would be used to convert PTT trainer simulation software into module trainer software during initial development.

Option (c) is all compatible non-DMS, so models could move easily from PTT to module trainer.

Option (d) would result in the minimum development cost since the module and part-task systems would have hardware and software of optimum size and functions for the respective simulation tasks. Two different models would have to be developed for module and PTT training however which would significantly increase operations and payload development costs.

#### Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) com- mon DMS plat- forms	Same or scalable host for each trainer type (+ all DMS Kits if F/E required)	Accommodates F/E instruments & panel and C&D panels	DMS S/W	Use same P/L models regardless
(b) hooks & scars, & convert	Common host I/F & common non-DMS I/O + special custom I/O H/W for FE P/Ls + Dev. Sys. MIPS for S/W conversion	Accommodates F/E instruments & panel and C&D panels	DMS S/W + Simulation S/W, where differing, must have hooks + S/W conversion utilities & I/O conversion programs SLOC= 15K + 50K SLOC LoFi DMS S/W sim	P/L model S/W, where differing, must have hooks + conversion labor per P/L
(c) com- mon non- DMS	Same or scalable host for each trainer type	No F/E instruments & panels	COTS S/W + ITVE & SSE replacement S/W	P/L models must conform to PTC I/F
(d) none	Host matched to trainer CPU & I/O loads (+ DMS Kits only where required)	F/E and sim in separate trainer types	DMS S/W + 50 K SLOC DMS Kit S/W sim	Use different or converted P/L models (2 required for each P/L)

**3.2.25 Attached Payload Representation:**

- a) use dedicated trainer
- b) attach to module/ use part-task trainers

**Training:**

Use of a dedicated trainer would allow more realism, plus greater availability of training time.

**System:**

Both options could increase the total number of trainers depending on training load schedules, but sharing of part-task trainers offers the opportunity to minimize any increase. Or, the attached payload trainer could be linked to a module trainer and treated as an additional payload, or set of payloads, within the module trainer.

Dedicated trainers will entail unique design and implementation work at additional cost. This option also increases the overall complexity of the PTC/SCS and the payload simulation system for the SSTF.

Additional (concurrent) and unique trainers place a greater load on system facilities and capacities by requiring more LAN and CPU capacity.

**Cost:**

Design and implementation costs will be higher for the dedicated trainer but the effort could borrow heavily from the part-task and module trainers, resulting perhaps in only a 10 to 15 percent increase over comparable module/part-task unit trainer costs.

**Comparison:**

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) dedicated trainer	Additional host + more LAN capacity + node trainer	F/E P/L with instruments from PIs	Set of standard module trainer S/W	F/E or model P/L S/W
(b) module/ use part-task	Any unique MDM features for attached P/Ls + additional module trainer host capacity	Same	2K SLOC reconfig. program*	Same

- \* Estimate for trainer reconfiguration function for options in Paragraph 3.2.17, "Consolidated Increment Training"

### 3.2.26 Payload Video Representation:

- a) dynamic
- b) canned playback

#### Training:

Dynamically generated video and/or rendered computer generated imagery would greatly improve the realism of the scenes, which in turn, would improve the training value of the simulations.

#### System:

The options are related to Paragraph 3.2.18, "POIC Interface" to the extent that the high rate science link can include video data. Video data is also transmitted to the POIC via a separate link. Video is presented on MPACs to the crew (trainees) and to instructors on their consoles.

Dynamic generation implies that a visual scene is being generated (with a graphics adapter) in response to real time payload, environment, and crew interactions. The scenes may also be selected and manipulated in real time from stored video data. Additionally, live (NTSC) video may be mixed with either generated source in real time. Coprocessor support of the video generation and mixing is assumed.

Canned playback may include any or all of the above mentioned video sources, but none of these sources would respond dynamically to simulated SSF, crew, or ground events. Instead, a pre-programmed (or pre-recorded) scene or animation would be presented.

The fidelity options distinguish between mixed or single source video modes, combined with 3D rendering or the more cartoonish "2 1/2 D" solid color displays and animations. The video adapter, display screen, and geometry CPU are all simpler and less expensive with 2D CGI (or NTSC) for a given raster resolution. Rendered computer generated imagery (CGI) plus NTSC becomes necessary when depth perception or apparent detail are relevant to training objectives. Mixing capabilities to overlay live or recorded NTSC video with computer graphics may provide a cost effective solution to achieving large volume or complex scene generation.

Because the (concurrent) use of payload video is expected to be low, the video generation subsystem may be centralized so it can be shared by all trainers. If usage is high, a related impact could be the addition of centralized optical disk or magnetic tape storage of payload video to support either type of video generation.

#### Cost:

Assuming that the canned video is provided by video tape, the additional cost of dynamic generation is that of a fast 24 bit graphics adapter with double buffered resolution of at least 800 X 600 lines, plus the cost of a real time video mixer to merge graphics and NTSC video. The ancillary host and LAN support for payload video generation is approximately the same for either option. Cost of the Audio/Video system can be kept down by the use of COTS software.

The use of 2D CGI (or NTSC) option does not include a video mixer to combine CGI with NTSC, or a specialized graphics adapter, embedded CPU, and processing software to support rendering.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) dynamic	dynamic generation requires A-V system unit* per several trainers	F/E P/L instruments & panels including video peripherals	6K SLOC A-V system programs + development toolset supporting dynamic video generation	P/L models capable of generating video
(b) canned playback	canned playback requires Video source & storage unit**	none	1.5 K SLOC simple A-V function included in trainer's Sim Exec	P/L models capable of triggering video

- \* The A-V System is taken to consist of a frame buffer, 10 MIPS graphics engine, mixer, general CPU of .5 MIPS, host I/F, and broadband network, plus peripherals including VCR/video-disk and CCTV camera

- \*\* Minimally, this capability can be satisfied with a VCR and/or CCTV camera





### 3.2.28 Payload Stimulation:

- a) full stimulation
- b) limited stimulation (for individual payloads)
- c) none

Payload stimulation is defined as realistic physical or electronic input that represents the SSF and external environment to the hardware payload simulation, including flight equivalent payloads.

#### Training:

For realistic simulation, stimulation must be provided. The stimulation signals/forces that will be necessary to evoke realistic performance (sufficient to satisfy training objectives) from hardware payload simulations will vary greatly from payload to payload.

Full stimulation would add little in training value over the judiciously selected stimulation offered in Option (b). Option (b) would selectively support hardware payload simulations with the minimum stimulation to evoke response that cannot be simulated. Payload stimulation is likely to be fashioned uniquely for each hardware payload simulation.

For Option (b), stimulation can be done by software in the host via the SIB connection to the MDM, SDDU, GSE port, or MDM ICE.

#### System:

Full stimulation would require a complex simulation of the SSF and external environment with associated hardware and software to drive the training simulator hosts.

Limited stimulation would only provide stimulation of high fidelity where needed. Based on training requirements, stimulation for many hardware payload simulations may be very simple or not provided. In some cases a simple manual input may be sufficient.

#### Cost:

A payload stimulator will minimally consist of several channels of input/output with analog-digital conversion and perhaps simple energy sources such as light and heat to stimulate hardware payload simulation sensors. Full stimulation will include more sophisticated energy sources such as magnetic fields as well as mechanical effectors under real time control. In some cases, direct connection to hardware payload simulation internals may be implemented to inject signals emulating the effects of external stimulation.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) full stimu- lation	Signal and energy supply fixtures* + .1 MIPS per P/L on MC/PA for control**	None unless unique I/F for H/W P/L simulations	4K SLOC control program**	H/W P/L simulations
(b) limited stimu- lation	Subset of Option (a) depending on individual training requirements	None	2K SLOC control program**	Same
(c) none	none	none	none	none

\* Payload stimulation includes electronic/optical signal (analog & digital), radiant energy, magnetic, mechanical input, etc.

\*\* Combined GSE and stimulation control function is estimated in Section 2.10, "GSE Control", of Appendix A.

**3.2.29 Instructors per Trainer :**

- a) one
- b) more than one

**Training:**

With the proper resources and system design, an increased number of instructors would provide a proportionate improvement in training over what one could provide.

**System:**

A simple design would be to connect an instructor workstation to the controlled trainer. This is a poor design from a reliability standpoint, since one failure could bring the whole trainer down. A better design would be to put the workstations on the LAN with associated software to allow any instructor workstation to connect to any trainer. This would eliminate this "single point of failure" problem. A further extension would be to increase the number of instructor workstations beyond the number of concurrently active trainers. This would allow for more than one instructor to control one training session. The only additional design consideration would be to deal with conflicting commands. A small system load will result from the requirement to provide controls to preclude conflict in addressing the same payload by different instructors. This load is included in the software estimates in the comparison table below.

The option of more than one instructor is assumed to apply only to module trainers (or consolidated trainers).

This cost driver also affects the bandwidth of the common audio/video link (because the audio/video feed, which is separate from the LAN, is individually selected).

**Cost:**

Because multiple instructors may be concurrently monitoring and controlling different payloads or aspects of the training scenario, the number of instructors will, in the worst case, cause the real time traffic load on the PTC/SCS Network to increase in proportion to the number of instructors. If instructors are assumed to have full capability for training session management (i.e. not partitioning of capabilities across instructors), the "more than one instructor" option will scale up the network load one 10 Mbps notch for every ten concurrent training sessions.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) one	8-10 WSs of 16 MIPS* w/ A-V + SCS LAN + 1.1 MIPS** on MC***	None	10K SLOC control & monitoring program (+ support from the Session Management Function & Sim Execs)	None
(b) greater than one	1 WS of 16 MIPS* w/ A-V + .1 MIPS on MC*** +1 Mbps increase on SCS LAN for each addt'n instructor	None	Program as above plus 2K SLOC for concurrency mgt.	None

- \* Workstation estimate for Instructor Station is per Section 2.11, "Instructor Control and Monitoring", of Appendix A.
- \*\* Instructor interaction with the Session Management Function is estimated at slightly more than 0.1 MIPS per payload.
- \*\*\* Sized to handle the given instructor complement in 6 concurrent trainer sessions.

### 3.2.30 U.S. Payloads in International Partners' Modules:

- a) use IP Data System Kits
- b) simulate their system
- c) treat as U.S. module payloads

#### Training:

Use of International Partner (IP) Data System Kits would provide high fidelity training with high crew confidence in the training.

#### System:

Option (a) is thought to be the most likely situation. This means that an International Partner (IP) Data System Kit must be supplied for each IP Part-Task Trainer or module trainer. The hardware and software required for Option (b) depends on the characteristics of the IPs' payload data systems for the SSF. Sufficient information to permit simulation is just beginning to be available. Option (c) might be viable if International standard P/L racks can be agreed upon. However, other issues arise, including the functionality of the IP Workstations.

#### Cost:

For Option (a), it is assumed that IP Data System Kits will connect to ITVE architecture A or B, and that the kits will be available from the IPs -- also, documentation, users manuals, spare parts, maintenance, etc. These Data System Kits must work with ITVE simulation control software.

For Option (b), hardware and software will be needed. Also designs of IP Data System Kits will be needed. Note that there will likely be schedule problems with this approach.

For Option (c), we will need more DMS kits and associated peripherals. Issues to be resolved include interfacing to IP FMPACs or ECWS.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) Int'l Kits	IP DMS kit w/ MDM + custom SIB w/ host I/F + FDDI bridge per trainer	H/W P/L instruments or panels	Int'l Partner DMS S/W + custom sim I/F programs	F/E P/L S/W or P/L model compatible with Int'l Partner DMS environment
(b) simulate	I/O Processor + host I/F + FDDI bridge per trainer	Same	40K SLOC simulation of each IP's DMS**	F/E P/L S/W or P/L model
(c) U.S. Kit	1 DMS kit for each IP trainer*	Same	Same as for other DMS kits*	F/E P/L S/W or P/L model

\* Complies with the trainer implementation as specified in Paragraph 3.2.6 "Use of DMS Kits".

\*\* Medium fidelity (approx 50% functionality) DMS simulation program, sized based on U.S. Lab DMS estimate per Paragraph 3.2.6 "Use of DMS Kits".

### 3.2.31 Trainer Host Reconfigurability:

- a) hot backup for US Lab Module trainers
- b) reconfigurable backup for US Lab Module trainers
- c) none

#### Training:

A hot backup (Option a) for US Lab Module trainers is potentially required for joint integrated simulations where the cost of a PTC/SCS trainer failure would be enormous. Up to fifty personnel dispersed at ROCs, DOCs, and UOFs worldwide, the computers and trainers at these sites, and all the communications resources connecting them could be idled by a PTC/SCS failure. The cost of training being stopped for hours, and then rescheduled would be unacceptably high. A hot backup could provide recovery and resumption of the joint integrated simulation in under five minutes.

A second potential solution to this same problem is reconfigurable backup. This would permit resumption of training in a known, relatively short period of time. If the period is some portion of an hour, this could be a cost effective alternate to Option (a).

#### System:

A true failover hot backup (Option a) for US Lab module trainers would require duplicate hardware from the C&D panel connections in the trainers on out to and including the host computers, frequent checkpoint of scenario data on a shared medium that is accessible to the duplicate hardware, and control software to monitor for failure and activate the failover when a failure occurs.

A reconfigurable backup (Option b) can be implemented by utilizing one of the other equally sized hosts (the IT&V host for example) with some switches and shared media to connect it in place of the failed host. The DMS Kit is the problem here, but current DMS design indicates that duplicate internal components or a duplicate SIB with a cross-bar switch could be utilized. If the duplicate internal DMS Kit component method is used, the SIB and key internal DMS Kit components including the MPAC then becomes the single points of failure. This is the current CBR baseline.

#### Cost:

The costs of hot backup (Option a) are the additional host, DMS Kit, bridges, switches, and shared media as well as more complex SCS executive software and failover software. The current SIB design, however, hampers easily reconfigurable DMS-based trainers due to the SIB's proprietary high speed, non-switchable point-to-point host connection. The SIB to DMS Kit connections, as well as flight equivalent payload hardware connections to MDMs, further limit the ease of reconfiguration.

The costs of reconfigurable backup include the cost of:



- duplicate SIBs and a cross-bar switch or a single shared SIB with duplicate host ports (and duplicate DMS component capabilities) with duplicate connections to C&D panels
- a duplicate MPAC (optional)
- duplicate C&D panel to host connections with switches between the connections
- a duplicate host
- shared media to hold the required checkpoint data
- additional patch panel routing of Audio/Video, C&T, and other simulation services using duplicate connections may also be necessary

**Comparison:**

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) hot backup	A standby host, dual ported disks (2 sets), standby DMS Kit including a 2nd MPAC and SIB + dbl path switches for connections from DMS Kit to C&D, DMS Kit to MPAC, host to C&D + duplicate A-V + 2nd C&T processor and patch panel	None	8K SLOC failover & reconfiguration program in the Session Management Function + 2K SLOC reconfig. module in each Sim Exec (+ common sim models for all trainers)	All P/L models must conform to a standard so that checkpoint can be done. F/E P/Ls may be a problem in this regard
(b) reconfig backup	Dual ported disks (2 sets), a SIB with duplicate component capability connected to IT&V host+ dbl path switches for connections from host to C&D	None	2K SLOC reconfig. module in each Sim Exec (+ common sim models for all trainers)	All P/L models must conform to a standard so that checkpoint can be done. F/E P/Ls may be a problem in this regard
(c) none	None	None	None	None

### 3.2.32 Malfunction Insertion:

- a) most conceptually possible faults, predefined & real time
- b) selected faults, predefined

#### Training:

Malfunction insertion is an important part of training. Option (a) will provide the best training, and will permit instructors good flexibility during a simulator session

The training value of this issue is directly proportional to the number of faults implemented.

Failures and near disasters in the nuclear power industry have demonstrated the importance of training for serious system failures. The experience gained there has shown that not only should all serious faults be simulated and trained for, but that secondary interactive sub-system failures should also be simulated. That is, situations like a ruptured high pressure line doing damage to nearby electrical lines should be simulated.

#### System:

For Option (a), a SIB would be used with flight equivalent payloads. Inclusion of the SIB provides a good level of capability for fault insertion in response to scenario or ad hoc control. Flight equivalent payloads, combined with DMS Kits, will be particularly effective for training interactive faults, as demonstrated in the SCS Study Technical Demonstration in August '89. Software payload models would have to be structured for interactive fault activation as well as containing some predefined faults that could be triggered during a session.

For Option (b), a SIB may not be required. However, if the SIB is not used, malfunctions in flight equivalent payloads would be limited to those designed into the hardware. This will likely be minimal. For software simulated payloads, the faults may be designed into the software models either as specific perturbations, or as a general capability to adjust functional processing to produce error prone behavior. In either case, the instructors would be much more limited in their ability to create faults that were not thought of as the payloads were designed. Usually, the malfunctions that cause problems are the ones not discovered during the design phase.

#### Cost:

Option (a) requires intervention during runtime to modify model behavior and, consequently, must be able to monitor the state of the simulation.

The development cost of Option (b) is less than Option (a) because it only requires access to software models during runtime to trigger the built-in predefined faults

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) most faults, pre-defined & realtime	Increase trainer host MIPS 1% + SIB or non-DMS SIB equivalent per trainer	F/E P/L simulations provide direct access to subsystem internals	DMS Kit S/W or equivalent and Sim Exec S/W or O/S (+ develop toolset) support ad hoc malfunction	5% more SLOC above nominal P/L model for increased P/L model fidelity & control
(b) selected faults, pre-defined	Instructor I/F to allow triggering of predefined malfunctions	F/E P/L simulations allow preprogrammed fault behavior	Sim Exec S/W to support fault triggering	10% more SLOC above nominal P/L model for S/W P/L models with enough faults to allow preprogrammed fault behavior

### 3.2.33 Simulator Modes:

- a) high = auto/variable play & record plus "med" functions
- b) med = freeze, resume, and replay plus "low " functions
- c) low = stop, restart and record only

#### Training:

The differentiation in simulator modes centers around the ability to start, freeze, and replay sessions, at will, from any point in the scenario. In option (a), this capability extends to defining the points automatically, based on simulation event characteristics. Option (a) is also distinguished by the ability to play and replay scenarios using condensed and discontinuous time scales and, in general, to support all the modes defined in Paragraph 3.3.2.1 of Volume 3 of the SCS study, "Refined Conceptual Design Report".

Option (b) requires manual invocation of the freeze, resume, and replay functions.

Option (c), on the other hand, has no capability to freeze (pause) and resume scenarios, or otherwise alter the course of chronological time in the scenario.

There is great training utility in having all the features of Option (a). When a student experiences difficulty, the student and/or the instructor can repeat an arbitrary section of the scenario. The ability to start the scenario at any point is very useful in that a particularly difficult section can be repeated.

#### System:

For Option (a), recording and replay capabilities require the systematic capture of scenario and crew events in near real time, and the ability to drive a scenario from the resulting pre-recorded crew and, possibly, ground operator events (rather than actual inputs from the lab module and ground systems). Thus, all initialization and real time inputs to the simulation have to be extracted and stored against a time base for possible replay of the session. Further, any stochastic components of the simulation models have to be monitored and all non-deterministic values recorded against the same time base.

In Option (a), the fast time, jump ahead, and other time base manipulations may require additional capabilities. These include coherent synchronization of events with discrete time jumps or sufficiently rapid model execution to achieve accelerated calculation of dynamic relationships. The general approach of faster cycle time would be the desired approach since the same software could be used. For example, the equivalent simulation update cycle could be increased from, say, 2 Hz to 24 Hz if a 12-hour flight shift were being condensed to one hour running time. This of course would require excess computation speed.

On the other hand, the coherent synchronization of events would be done by building software models that were passed the current time or the time since the last call to the models. The models themselves would then calculate the resulting stated based on the time variable. This is the method used in the current shuttle simulator. While both methods are considered in this analysis, it is most likely that the coherent synchronization method will actually be used.

If the session recording function resides primarily under the Session Management Function rather than individual simulation executives there is potentially a substantial load on PTC/SCS LAN and storage. Although, storage space can be conserved by storing simulation parameters only when their values change, this approach may carry a significant overhead (in the simulation executive) for monitoring and detecting change. Overall, however, it is the complexity of synchronization, rather than storage space that will vary with these storage options.

Option (b) is the same as Option (a) minus the "auto/variable play & record". This reduced functionality would require far less system resources, since the excess computational speed associated with "fast time and jump ahead" would be eliminated.

Option (c) has a minimal impact on system resources.

The inclusion of mode controls in the simulation scenarios requires additional capability in the scenario development system. Likewise, the execution of replay and jump capabilities require additional functionality in the instructor station.

The ITVE simulation executive is expected to support all simulation modes required by the PTC/SCS, except resume.

#### Cost:

Options (a) and (b) assume much of the same monitor functionality as required for trainer fail-over in Paragraph 3.2.31, "Trainer Host Reconfigurability". In addition, the system must continually capture and record the state of the simulation, or at least keep a running log of all trainee and instructor inputs. When rerun under the original scenario, this log must enable a complete replay capability.

If the variable speed method is used to implement the "fast time" and "jump ahead" capability, there will be a substantial impact on the cost. While variable speed simulation is basically a software control function, the increase in host CPU capacity required will be nearly proportional to the speed of the fast-time simulation mode. Thus, a fast-time speed of 5 times normal will result in about a 400 percent increase in the CPU MIPS required to execute the simulation models.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) high	1 MB RAM capture/recording per second* (+ SIB-like I/O ctrl) + add'l 2 MIPS on MC per P/L ** trainer + 300 MB disk or tape per session	F/E P/L instruments provide direct access to internals	F/E DMS & MDM, model DMS, SIB, Sim Exec, and the Session Management Function S/W support global sim. memory, and halt & resume functions (approx. 7K SLOC)	F/E & model P/L S/W support global sim memory, step ahead, and halt & resume functions
(b) medium	1 MB RAM capture/recording per second* (+ SIB-like I/O ctrl) + add'l 1 MIPS on MC per P/L ** trainer + 300 MB disk or tape per session	F/E P/L instruments provide direct access to internals	F/E DMS & MDM, model DMS, SIB, Sim Exec, and the Session Management Function S/W support global sim. memory, and halt & resume functions. (approx. 3K SLOC)	F/E & model P/L S/W support global sim memory, and halt & resume functions
(c) low	1 MB RAM capture/recording per second*	None	F/E & sim S/W w/ basic reset control (approx. .5K SLOC)	F/E & model P/L S/W support global sim memory

\* Assumes that a global simulation memory exists with a rate of change not greater than 1 MB per second (approx. 50K variable deltas) for the trainer session

\*\* Based on full payload model execution at 5 times update rate and corresponding MIPS (for minimal speedup)

### 3.2.34 Session Data Handling:

- a) full data capture and analysis
- b) record keeping only

#### Training:

No significant impact on training but does affect the quality of analysis of trainee performance.

#### System:

The recording capabilities used to accomplish session replay in Paragraph 3.2.33, "Simulator Modes", may also be used to capture the session data necessary to evaluate crew (trainee) performance as well as collect scenario and schedule information for training records. Only the latter function, without the need for evaluating real time data, is included in Option (b). Option (a) would not only capture the crew (trainee) input script, but also external ground operations and model generated events and valuations.

Primary storage capabilities, as well as statistical analysis and record keeping functions, would be implemented as PTC/SCS system facilities. Note that Option (a) is assumed to include representation of external ground operations.

#### Cost:

If either Option (a) or Option (b) of Paragraph 3.2.33, "Simulator Modes" is in place, there should be no additional cost involved in achieving the data capture functionality. The analysis function for Option (a) in the present issue, however, will entail additional cost for analysis software and storage facilities to retain these data and analysis results. The former probably represents only the cost of a COTS statistical package and database package plus some custom applications work - in total not more than 12K SLOC. Disk storage capacity could accumulate to several hundred megabytes before trainee data would be archived at the end of an increment's schedule.

Comparison:

	HARDWARE REQUIREMENTS		SOFTWARE REQUIREMENTS	
	FIXED	INCREMENTAL	FIXED	INCREMENTAL
(a) full data	1 MB RAM capture/recording per second* + A- V recording per trainer	None	F/E & sim S/W supporting global memory or ease of local access + COTS DB & statistical analysis package + programs in the Session Management Function (approx. 12K SLOC)	F/E or model P/L S/W supporting global memory or ease of local access
(b) records only	None	None	COTS DBMS + programs in the Session Management Function (approx. 2K SLOC)	F/E or S/W P/L models support I/F to DBMS

- \* Assumes that a global simulation memory exists with a rate of change not greater than 1 MB per second (approx. 50K variable deltas) for the trainer session





## Report Documentation Page

1. Report No.  N/A	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle  Simulation Computer System (SCS) Baseline Architecture Report		5. Report Date  December 1990	
		6. Performing Organization Code	
7. Author(s)		8. Performing Organization Report No.  N/A	
		10. Work Unit No.	
9. Performing Organization Name and Address  TRW, Grumman, Essex		11. Contract or Grant No.  NAS8-37745	
		13. Type of Report and Period Covered Study Report Jan 90 - Dec 90	
12. Sponsoring Agency Name and Address  NASA MSFC E035 Huntsville, AL 35812		14. Sponsoring Agency Code	
15. Supplementary Notes NASA Contact - Michael Watson, MSFC, E035 TRW - Jeff Jensen, 213 Wynn Drive, Huntsville, AL 35805 Grumman - Michael Denny, 1000 Woodbury Road, Woodbury, NY 11797 Essex - Dan Dodson, 690 Discovery Drive, Huntsville, AL 35806			
16. Abstract <p>NASA's Space Station Freedom program (SSFP) planning efforts have identified a need for a payload training simulator system to serve as both a training facility and as a demonstrator to validate operational concepts. The envisioned MSFC Payload Training Complex (PTC) required to meet this need will train the Space Station payload scientists, station scientists, and ground controllers to operate the wide variety of experiments that will be onboard the Space Station Freedom. The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex at MSFC.</p> <p>The purpose of this SCS Study is to investigate issues related to the SCS, alternative requirements, simulator approaches, and state-of-the-art technologies to develop candidate concepts and designs.</p>			
17. Key Words (Suggested by Author(s))  Space Station Payload Training Simulator Computer		18. Distribution Statement	
19. Security Classif. (of this report)  UNCLASSIFIED	20. Security Classif. (of this page)  UNCLASSIFIED	21. No. of pages  169	22. Price

